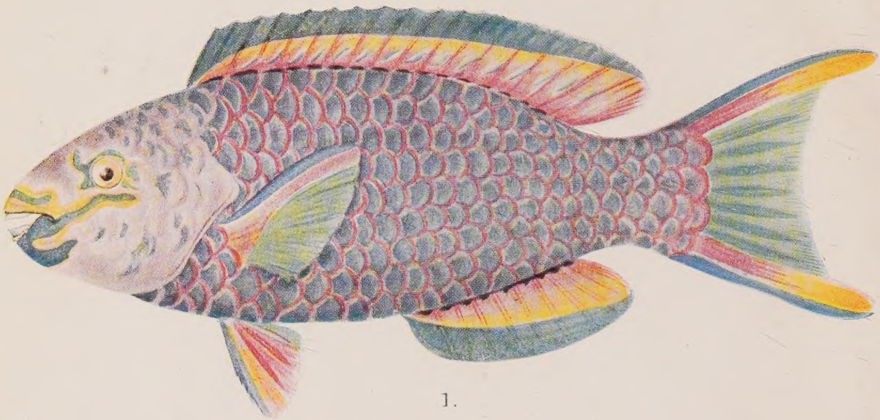
HE ANIMAL AND ITS ENVIRONMENT

PLATE I.



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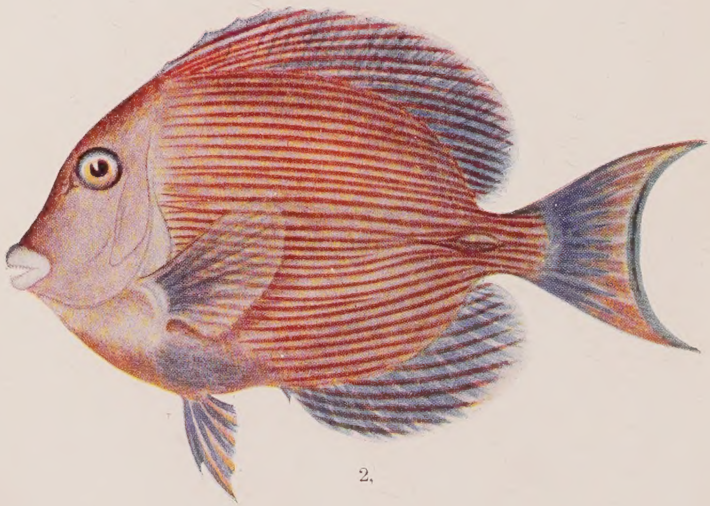

2.

LITTORAL FISHES OF THE TROPICS.

FIG. 1.—*Scarus vetula*, a West Indian Parrot Fish. Note the strong teeth with which the fish browses upon corals, etc.

FIG. 2.—*Teuthis coeruleus*, the Doctor Fish. The spines on the tail inflict poisoned wounds.

The effect of the colouring is even more brilliant in species in which a single bright hue is uniform or predominates.

THE ANIMAL AND ITS ENVIRONMENT

A TEXT-BOOK OF THE NATURAL HISTORY OF ANIMALS

BY

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PREFACE

The need for a systematic survey of the relations of individual animal organisms to their surroundings has been growing for some time. In the following pages I have endeavoured to do something towards meeting it. The ground to be covered is so vast that, within the limits to which I could go, little more could be done than to sketch the framework of the subject; but I have tried here and there to clothe it with some detail. The student should understand that when I have cited examples of the various phenomena with which I have dealt, the lists are almost never complete, and with a little reflection can be supplemented from knowledge which he possesses. I would ask indulgence for the necessary omission of many striking and important facts, as well as for the errors that I cannot hope to have avoided.

A few matters of treatment call for some explanation. The book has been planned primarily for the use of Students, though I hope that other readers may find it of interest. I have as far as possible avoided all reference to theories of Evolution—either as to the course which that process has taken or as to the way in which it has been brought about. Important though they are, these subjects are but remotely connected with that of the relation between the individual and its surroundings, which is best studied for its own sake. At times, however (as when it has seemed of interest to consider how the faunas with which animals are in relation have come into being), questions of Evolution have necessarily intervened. I have made much use of English names for species and groups of animals, though I have given the Latin names as well. In my experience, the student is retarded and disheartened, now more than formerly, by the unfamiliarity of the terms in which a science is expressed. Owing to lack of space in certain parts of the book it has not been possible always to

place illustrations where the text has most need of them, though they are never altogether out of touch with the matter. This defect has been remedied as far as possible by references, to which the reader is accordingly asked to pay heed. A good deal of use has been made of the legends of the figures to convey information.

I have to offer my best thanks to various gentlemen who have helped me. Professor J. Stanley Gardiner, Mr. J. Gray, Mr. F. A. Potts, Mr. J. T. Saunders, and Professor James Ward have each read a part of the book and have given me the benefit of their advice and criticism. Dr. G. P. Bidder kindly lent me a drawing. Messrs. George Allen & Unwin Ltd.; Edward Arnold & Co.; George Bell & Sons Ltd.; Bibliographisches Institut A.-G.; A. & C. Black Ltd.; Cambridge University Press; Cassell & Co.; Columbia University Press; The Encyclopædia Britannica Co. Ltd.; Verlagsbuchhandlung Gustav Fischer; Kegan Paul, Trench, Trübner & Co.; Little, Brown & Co.; Longmans, Green & Co.; Macmillan & Co. Ltd.; The Macmillan Co. (New York); Masson et Cie; Methuen & Co. Ltd.; John Murray; George Newnes Ltd.; George Routledge & Sons Ltd.; Schweizerbart'sche Verlagsbuchhandlung; Taylor Bros. (Leeds); Verlagsbuchhandlung von B. G. Teubner; Thornton Butterworth Ltd.; and Williams & Norgate; also H.M. Stationery Office; the British Museum (Natural History); the Carnegie Institution of Washington; and the National Geographic Society (Washington, D.C.), have permitted me to reproduce illustrations from works owned by them. My acknowledgments to the authors from whom I have borrowed are made in the legends of the figures.

L. A. BORRADAILE.

SELWYN COLLEGE, CAMBRIDGE,
December 1922.

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THE ANIMAL AND ITS ENVIRONMENT

CHAPTER I

INTRODUCTORY: THE ORGANISM AS AN OBJECT IN NATURE

The living being, like other things that hold the attention and stir the imagination of mankind, shows different sides to different men. To the biochemist it is a problem of physical chemistry, to the philosopher one of determinism, to the morphologist one of descent. The plain man's view of it is less penetrating but more comprehensive than any of these. To him it is still, as it was when he played the children's game called "animal, vegetable, and mineral," *an object in Nature*, to be likened to and differenced from other objects, and of interest because of its relations to the rest of the world. He judges whether this thing or that be alive, and if it be he knows that it will affect and be affected by things around it as it would not if it were lifeless. Now this view of the living being is fully as instructive as any of the others. In most of the sciences the organism is studied in such a manner that it becomes but a special case of certain phenomena that appear also in other things, and its peculiar features are lost sight of: but regarded as an object in Nature it gains attention precisely by its difference from objects of all other kinds, and interest by relations with the world about it which are, as we shall see, the expression of that difference.

If we ask ourselves what it is that distinguishes a thing that is alive from one that is lifeless, we shall find the answer, not in any matter of shape or composition, not even in the fact that it is the seat of activity, but in the nature of that activity. *A thing is alive when there is going on in it a process by which it preserves its existence and that of its kind.* That process we know as its life. The energy for it comes, as is well known, from the disintegration, usually with oxidation, of the substance of the body. It is spent

in *movement*, by which unfavourable circumstances are avoided and food obtained; in the *chemical manufacture* of substances which make the food available by digestion and perform other services for the body; in bringing about that exchange with the surroundings of carbon dioxide for oxygen, known as *respiration*, which enables the oxidation to go forward; in the *excretion* of injurious waste matters which result from the disintegration; and in the *building up*, from the food, of living matter which replaces that which is lost in disintegration and provides material for the formation, by fission, of new individuals to *reproduce* the species and thus to continue or even to increase it in the face of loss by death. A part of life, such as the beating of the heart or the restlessness of a hungry animal, is spontaneous action, arising within the body; a part, as when the mouth waters at the smell of food, or on the coming into sight of an enemy the animal flees or turns to fight, is a reaction to external events. We must notice, however, that all life is solely concerned with the welfare of the race of beings in which it occurs, and that it is always directed outwards, and every phase of it leads ultimately to action and reaction upon the world.

The process that has just been described is the only character that is peculiar to living beings. But there is another feature that is highly characteristic of them, and only cannot be said to be peculiar to them because it is found also in their dead bodies and in certain things, such as machines and societies, which are made by them. This is *organization*. It consists in their being composed of a number of parts or *organs*, that are adapted to act together, each with a different task, to carry on the work of the whole—which is, in a living being, its life. Organization is of course a familiar feature in the higher plants and animals, in which every one recognizes the organs of nutrition, circulation, respiration, excretion, movement, perception, reproduction, and so forth, but in greater or less degree it is to be found in all living things. According to the extent to which it is developed—that is, to the specialization of the tasks of the organs—one organism is said to be more or less highly organized than another, as a man is more highly organized than a jelly-fish; but it is important to notice that creatures of the same grade of organization may be very differently organized. Thus, it is hard to judge whether a fish or a bee be the higher organism, but their organizations are utterly different.

A third character of the objects that are called living beings is less obvious than those we have mentioned, but it is now known to most educated people. It is that their bodies contain the substance known as *protoplasm*, which is, indeed, the only part of them

that is truly alive. Protoplasm is a viscid solution of complex organic compounds, mostly the colloidal nitrogenous bodies known as *proteins*, with salts, in water. It is not stable: its components are constantly undergoing chemical and physical changes. Moreover it is extremely sensitive, that is, changes in it are easily brought about, or modified, by external events. In it there go on the chemical changes—known, together, as "metabolism" —that by disintegration set free the energy of life and by synthesis rebuild the substance of the body. From it the secreta and excreta are shed out. By its changes of shape, technically known as "contraction," all the movements of the body are brought about. Out of it, at fission, are formed the eggs or other reproductive bodies from which new individuals arise. Rarely, however, does the whole body consist, as it does in the *Amœba*, of protoplasm only. Usually it is supported and protected by a skeleton or shell of dead "formed material," which may be of lime salts, as in bone, or flinty, or of some organic substance, such as horn or the cellulose that forms the skeleton of plants.

To sum up, it may be said that a living being is an object in Nature, composed of protoplasm with or without formed material, whose substance disintegrates so as to set free energy, which it expends in a complicated process that tends to maintain and increase it and its kind through action and reaction upon its surroundings; and that it is enabled to carry on this process by the fact that it contains various organs each of which plays some necessary part in the process as a whole.

It will be seen that the activity of living beings places them in a relation to their surroundings which is entirely different from that of lifeless things. In action and in reaction they have an efficiency and a persistency of their own. There are, indeed, lifeless objects which affect their surroundings by the discharge of energy liberated by the disintegration of their substance, either spontaneously, as in a mass of radium, or under the influence of the surroundings themselves, as in the dead body of an organism decaying under the influence of bacteria or fungi. In these cases, however, the energy discharged never performs upon the surroundings of the object any task for the benefit of the latter, but is for the most part dissipated ineffectively as radiation, and sooner or later brings itself to an end by destroying the body which is exhibiting it. Even radium is slowly lessened by its activity. Quite otherwise is it with the living body. The energy which is liberated there is for the most part directed to bring about definite mechanical and chemical effects upon the surroundings, and the work which it

does is unending, since it provides for its own continuance by repairing the waste which it causes, and even for its increase by bringing about growth and reproduction. The lifeless object is passive in face alike of favourable and of unfavourable circumstances. Neither spontaneously nor in response to external events does it avail itself of means of increase or avoid dangers. When it grows, as a crystal or a stalactite grows, that happens by no activity of its own. When the forces of the outer world attack it—by heat or cold, by drought or moisture, by mechanical injury or solution—it neither avoids nor protects itself against them. If they cause in it internal disintegration, it takes no steps to repair the waste. If they destroy it, it leaves no offspring to continue its race. But the living being is a machine of great efficiency which in all these and other ways acts and reacts for its own benefit. In so doing it is engaged in the "struggle for existence." The result of this is in the organism ability to exist, delicate and labile though its protoplasm is, amid surroundings which are exerting upon it powerful and destructive forces. In the world as a whole the result is a complication of the action of its forces which is a factor of enormous importance in the system of Nature. By the living machine these forces bring about results which they could not otherwise accomplish. The history of this process is writ large in the very substance of the earth. Enormous beds of chalk and limestone composed of the skeletons of minute marine organisms, the world's supply of coal, countless coral reefs and islands, vast areas covered with vegetable mould by the action of plants and earthworms, and great tracts of country whose face has been changed by human activity, bear witness to its existence; and since the coming of Man it has progressed by his agency more and more rapidly, till it promises to dominate every other terrestrial agent of change. It is interesting and important to reflect that, other things being equal, the smaller an organism the greater is the part which, for its size, it plays in the economy of Nature. Not only is the absolute thickness of the coverings by which the bodies of most organisms are shielded less, on the average, in small species than in large, but, since the volume of an object increases as the cube of its dimensions, while its surface

Fig. 1.—Limestone composed of fossil foraminifera (*Nummulites*).—From Thomson.

increases as the square, a small organism has, potentially at least, a relatively greater surface upon which to conduct its traffic with its surroundings—to lose, for instance, heat or moisture, so that it must be more active in replenishment, or to carry on that exchange of materials by which, especially in water, organisms affect the composition of the media that bathe their surfaces. A mouse consumes relatively more food than a horse, and the minute floating plants of the sea are, bulk for bulk, infinitely more important chemical agents of Nature than the whales.

On the other hand, vigorous and effective though their struggle for existence is, organisms are severely restrained by their surroundings. It is only within certain limiting conditions that they can exist at all. (*a*) The first of these conditions is the presence of water. As we shall see, that liquid performs various indispensable functions in bodies: at present we need only recognize that it is an essential constituent of protoplasm. It must be available in the neighbourhood of all organisms. (*b*) Temperature has also a part in determining the possibility of life. Above a certain temperature, proteins in solution coagulate, and thus protoplasm is altered so that life is brought permanently to an end. At low temperatures the chemical processes of life, like others, are slowed down, and when protoplasm freezes they are stopped, often for ever. The upper limit of temperature at which life is possible in animals varies from about 45° C. to about 55° C.; the lower limit is that at which frost destroys an essential tissue. The optimum varies greatly. Typically it is perhaps between 20° C. and 40° C. (*c*) It is needless to prove that a supply of food is necessary for organisms, or that their needs differ in this respect; but it is important to note that each organism requires several kinds of material, and that its increase is limited by the amount of that food-stuff which is available in minimum quantity, as a plant, in the presence of plenty of carbon dioxide, water, and salts, cannot increase when it has exhausted the nitrates. This is known as the "Law of the Minimum." (*d*) Needless also to show, the presence of enemies sufficiently powerful and numerous makes life impossible for any species of organism. (*e*) For the life of green plants, and thus indirectly for that of animals which feed upon them, light is necessary. When all these conditions are present, organisms can exist; but unless each condition be at an optimum, defect in it will hamper them. Ideal conditions of life would be such that hindrances did not exist, and the whole energy of organisms could be devoted to the absorption and assimilation of food, to growth, and to reproduction. For a brief period, an embryo in the body of a

healthy, warm-blooded mother is perhaps in this state, but no other organism lives under ideal conditions, and each must expend energy, in activity and in the construction of organs, to overcome those that are unfavourable. It must seek, or obtain by effort, necessities, such as food, water, or oxygen; or it must break up or digest food that is in an unsuitable condition for absorption; or it must react against adverse events, such as the attacks of enemies or a fall in temperature. Usually it must do all these things. The optimum conditions of life are probably most nearly reached in the moderately shallow waters of tropical seas, where organisms are immersed in warm water which contains the salts which are indispensable to protoplasm, and both light and food are abundant. But in such places the struggle against living enemies is very severe. There, as everywhere, the conditions of life are such that organization must be adapted, not merely to taking advantage of opportunities of life, but to overcoming more or less unfavourable circumstances.

Lastly, we must note that it is very important for the organism that the conditions in which it is living should not change too much or too suddenly. Such conditions are never quite constant. Temperature, food supply, etc., vary from time to time for every individual. To the normal variability of its circumstances the living being has powers of adjustment. If these be exceeded, it will perish of cold, or heat, or drought, or starvation. Especially is it necessary that alterations should be gradual. Sudden changes tax the organism far more than those that take place slowly.

So far we have dealt only with the features that living beings have in common. We have now to consider the obvious fact that such beings differ enormously, both in organization and, correspondingly, in the activities of the body. Like the organisms themselves, their differences may be considered from various points of view. From that which regards organisms as objects in nature, most of the differences between them are seen to be related to one or other of the two facts: (*a*) that organisms live in different surroundings, and must therefore act and react differently; (*b*) that in the same surroundings they meet the stress of circumstances in different ways, in that either they use differently the same organs (which accordingly differ somewhat in form), or they perform the same functions by the use of different organs. Thus, for instance, (*a*) organisms that live in air are subject to very different conditions (of moisture, of the exchange of gases with the medium which surrounds them, of support by it, of changes of temperature, etc.) from those that affect organisms living in water, and we find between

the two sets of creatures such differences as those between a bird and a fish. Again, (*b*) of two birds living in the same locality, one will feed on seeds and have a stout, hard bill and a strong gizzard; the other will with the same organs capture and digest insects and like creatures, and in it the bill will be soft and flat or slender according to the prey it prefers, and the gizzard will be weak. Or, to cite wider differences, of two insects flying in

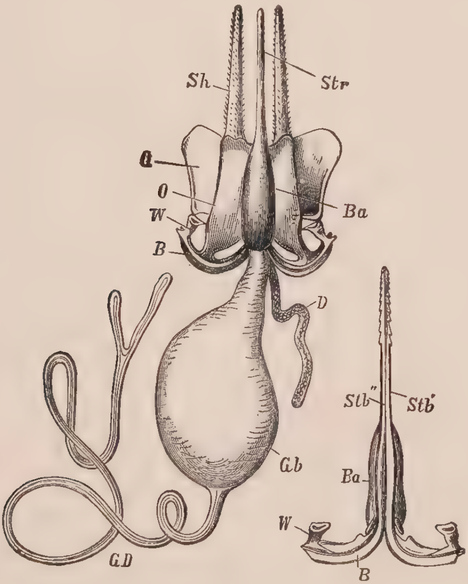


FIG. 2.—The stinging apparatus of a honey bee.

B., Curved root of the "director"; *Ba.*, swollen base of the same; *D.*, gland; *Gb.*, poison reservoir; *GD.*, poison gland; *O.*, "oblong plate"; *Q.*, "quadratic plate"; *Sh.*, sheath; *Stb′.*, *Stb″.*, the two piercing spines on the ventral side of the director; *Str.*, director; *W.*, "angular piece."

The apparatus which in Fig. 142 an ichneumon fly is using to deposit eggs, is composed of the same parts as this sting.

the same field, one makes use of an organ at the end of the body for depositing eggs, the other defends or provisions them with it, using it as a sting; and the limb that serves one arboreal vertebrate for climbing will in another become a wing. On the other hand, an insect and a bird perform in the same way the same function—flight—but do so by means of organs which, though they are called by the same name—wings—are of totally different construction, for the wings of an insect are folds of the

skin of the back, while those of a bird are limbs, corresponding to the arms of a monkey. So a fish and a lobster both breathe by passing water over organs known as gills, but the gills of a lobster are appendages of the legs, and those of a fish are folds of the lining of clefts at the sides of the throat.[1] Thus there exists between the peculiarities of organisms and those of their surroundings a connection which may be summed up by the statement that the structure and physiology of every organism are such as to enable it to cope with the circumstances amid which it normally passes its life; and that any circumstance may be met by organisms in various ways. To discuss how this correspondence may have been established — whether that has taken place, as Lamarck held, by inheritance of the direct action of the surroundings upon individuals or, as the Darwinian school maintains, by "natural selection," from spontaneous varieties, of the fittest to survive, is no part of the intention of this book. It belongs to the study of Evolution, and that subject will only incidentally be mentioned here. It is enough that we should recognize that life must have begun in some simple organism which came into existence in conditions favourable to naked and unorganized protoplasm, and that from that organism all the host of living beings have arisen by descent with modification, taking up ever new and more exacting locations and modes of life as they became fitted to do so.

Besides possessing each an inherited organization adapted to its normal surroundings, and making suitable use of it, organisms are liable to differ owing to another kind of relation to the environment. The stubborn fight of the individual to maintain its existence is paradoxically combined with a certain plasticity under divers factors of its surroundings. Thus we shall see that light, temperature, the nature and concentration of salts in a watery medium, its reaction, its currents, the food available, the size of the area, etc., have during growth an effect upon the structure and physiology which is being set up, and may even alter those of an adult. Some such modifications are adaptive, as is, for instance, the thickening of fur under the influence of cold. Others, such as the effect of salinity upon the Brine Shrimp (p. 260), do not appear to be so. Concerned as we are with the individual as an item in the economy of Nature, these directly-produced features, being small, and for the most part non-adaptive, are not an important part of our subject,

[1] In morphological language, organs which differ fundamentally in origin and constitution but have the same function are said to be analogous but not homologous.

and we shall do little more than allude to them in passing, as occasion arises.

It is sometimes held that there are peculiarities of organisms which neither adapt them to their surroundings nor are impressed by the latter upon them. If such features exist they do not concern us here.

The greatest of the differences between organisms are those which sunder the Animal Kingdom from the Plants. These are not of the kind which is connected with difference in the environment, but consist in a fundamental unlikeness of mode of life which is independent of the surroundings. At bottom they rest upon a difference in nutrition. Animals and plants alike are faced with the necessity to feed their protoplasm with the complex substances which are essential to it. Whatever their environment, they obtain these each in its own way. The green plant, possessing the power of using directly, by means of its green pigment, *chlorophyll*, the energy of certain of the sun's rays turns them to the task of breaking up the molecules of carbon dioxide, setting free the oxygen and building up the carbon, first with the elements of water into carbohydrates, and then with nitrogen, sulphur, and sometimes phosphorus, which it obtains from salts, into proteins. Thus it absorbs from its surroundings, through the surface of its body, simple diffusible, inorganic substances (carbon dioxide, water, and salts); and the form of its body is such as to expose as great a surface as possible. Further, perhaps because of the great supply of carbohydrates which its mode of nutrition provides, its skeleton is composed of cellulose, and this penetrates to the recesses of its tissues, stiffening them so that the great surface of the body is supported, but hindering, or rendering impossible, movement. The animal, on the other hand, not possessing chlorophyll, is unable to use directly the energy of the sun's rays, and therefore cannot build up, as the plant does, the complex organic substances necessary for the food of its protoplasm, but must obtain them ready-made. In the long run there is only one source from which it can do this — the bodies of plants and from this source the animal feeds, either directly, if it be a vegetarian, or through the bodies of animals which have fed on plants, if it be carnivorous. Thus, unless it be one of those parasites which absorb through their surface the juices of their hosts, it takes its food through a mouth; and the shape of its body and the nature of its tissues are such that it is mobile, to roam in search of, or at least to seize, its food. It never has a skeleton of cellulose.

Certain organisms, such as the Fungi, have a mode of nutrition

which is, in a sense, intermediate between that of the animals and that of the green plants. Not possessing chlorophyll they are unable to use substances as simple as those which the green plant uses, but the materials which they import are much simpler than those of the food of animals, and are absorbed through the surface of the body, and many such organisms form cellulose.

The fundamental difference in nutrition between animals and green plants has important results in their relations with the rest of Nature and with one another. In their action upon the inorganic world these two kinds of organisms bring about precisely opposite changes, and do so in such a way that each sets up conditions favourable to the activity of the other. The plant, absorbing the energy of the sun's rays, builds up with storage of that energy complex organic compounds from simple inorganic substances.[1] These manufactured substances it assimilates, partly in repairing the waste in its protoplasm, but mainly in adding to its substance by growth. Its construction of organic materials is in excess of its destruction of them, and the net result of its activity is to provide an accumulation of those complex substances which form a necessary part of the food of protoplasm. At the same time it sets free oxygen. The animal, on the other hand, obtains the organic food for its protoplasm by consuming the substances manufactured by plants, either directly from the plant body or after they have been incorporated in a somewhat altered form into the protoplasm of other animals. In the protoplasm of the animal these substances undergo destruction. Thus the animal destroys organic material without, like the plant, manufacturing from inorganic matter more to replace it. The net result of its life is to lessen the amount of organic matter in the world. At the same time it sets free carbon dioxide and fairly simple compounds which contain nitrogen in the form of ammonia. By a remarkable piece of chemical activity on the part of certain bacteria, these nitrogen compounds are oxidized first into nitrites and then into

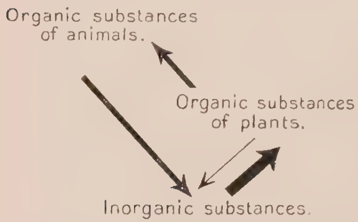


FIG. 3.—A diagram of the circulation of matter through the bodies of organisms.

[1] The storage of energy is, of course, due to the fact that more is absorbed in splitting the stable inorganic molecules than is freed in forming the unstable organic molecules.

nitrates, and in this form they are suitable for the food of plants.[1] Plants, therefore, provide food and oxygen for animals, while animals, destroying this food, provide for the use of plants simple nitrogen compounds and carbon dioxide. The result is a circulation of nitrogen and carbon through the bodies of organisms. It will be seen that this circulation of matter is accompanied by a transference of energy. The whole of the energy of the life both of plants and of animals is derived in the long run from the energy of the sun's rays stored by plants in the complex substances they manufacture. It is stored by plants: most of it is not set free till it reaches the bodies of animals. There is, of course, no circulation of energy. That which is set free from the bodies of organisms is lost to them, and has to be replaced by the fixing of more energy from the sun's rays by plants, when they build, largely from the excreta of animals, fresh supplies of organic substances. The whole animal kingdom may be regarded as a vast complex system which, by means infinitely more subtle than those which are possible in the inorganic realm, disposes of the material and energy accumulated by plants.

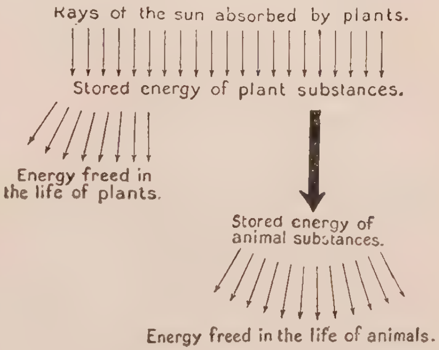


Fig. 4.—A diagram to show the history of the energy of organisms.

Even when organisms are dead, the materials of which they are built follow this cycle. Much of the body of a dead animal or plant, whether or not it have been killed for food, will sooner or later be devoured and reduced to simple substances by other animals, large or small. A whole series of *scavengers*, from large carrion-feeders, such as hyenas and vultures, through insects and their larvæ, such as burying-beetles and blowfly maggots, to minute round-worms and protozoa, lives by destroying in this way the dead bodies of organisms which its members have not killed. What escapes is attacked by bacteria, which obtain the energy for their life in transforming such matter into simpler compounds by fermentations which are often putrefactive. In the process it

[1] This is not the only way in which the supply of nitrates is provided for plants. Besides supplies from unorganized sources, a considerable amount of free nitrogen is fixed by bacteria.

FIG. 5.—Sexton beetles (*Necrophorus vespillo*) at work.

FIG. 6.—Minute nematode worms scraped from the body of an earthworm which has been decaying in damp soil for three days. Highly magnified. These worms are contained in the soil as encysted larvæ. In the dead bodies of animals they rapidly become adult, pair, and produce a new generation of larvæ which in turn encysts.

is rendered more soluble, and some of the smaller animals which derive their nourishment from dead bodies feed upon them not directly, but after they have been dissolved by bacteria. Others swallow the bacteria themselves. Finally, by a second set of bacteria, the dissolved but undevoured remains of the bodies undergo a further fermentation which transforms them into carbon dioxide, water, and ammonia, so that their fate is the same

FIG. 7.—Bacteria of decay.

a., *Bacillus vulgaris*, the principal bacterium of decaying flesh. It inhabits the intestines of animals, and thence spreads through the body after death. *b.*, *Bacillus subtilis*, the Hay Bacillus, very common in wet, decaying plant tissues, and also capable of living in dead animal bodies. It is a spore-forming species, air-borne, and is present in all sorts. *c.*, *Bacillus coli*, the commonest bacterium of dung. It is a constant inhabitant of the intestines of mammals and thus infects the dung. It is also found in decaying flesh.

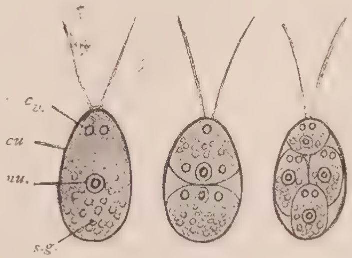


FIG. 8.—*Polytoma uvella*, a saprophytic flagellate organism found in infusions of decaying animal matter, where it lives by absorbing products of the action of bacteria. The figure shows stages in reproduction by binary fission repeated to form four individuals.

cv., Contractile vacuole; *cu.*, cuticle; *nu.*, nucleus; *s.g.*, grains of starch formed by the *Polytoma*.

as that which would have awaited them if they had continued to form part of a living body. The same road is travelled by

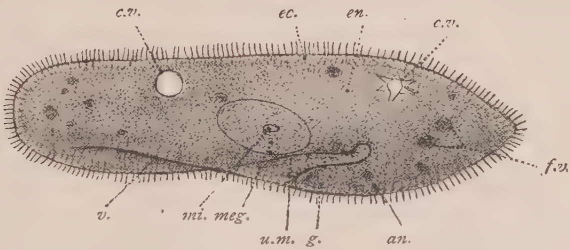


FIG. 9.—*Paramecium caudatum*, a ciliate protozoan, commonly found feeding upon the bacteria and other organisms which are present in water in which the remains of plants are decaying.

an., Position of temporary anus; *c.v.*, contractile vacuole; *ec.*, ectoplasm with trichocysts; *en.*, endoplasm; *f.v.*, food vacuoles, *g.*, gullet; *meg.*, meganucleus; *mi.*, micronucleus; *u.m.*, undulating membrane; *v.*, vestibule.

the undigested remains of organisms which are cast out from the intestines of animals. They are transformed into simple substances

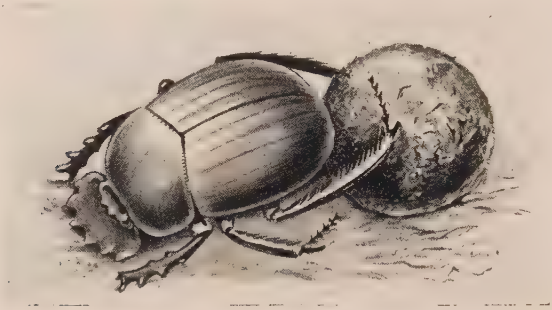


FIG. 10.—The Sacred Dung beetle (*Scarabæus sacer*) transporting its dung-ball. The animal is walking backwards, rolling the ball by means of the legs of the hinder pair. The combs upon the head and forelegs are used for raking the dung, the curved femurs of the hinder two pairs for shaping the ball, the spurs with which these legs are provided for holding it.

by a set of dung-feeding scavengers like those which deal with dead bodies. Dung beetles, the larvæ of dung flies, worms of various

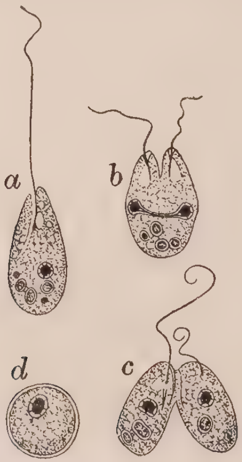


FIG. 11.—*Copromonas*, a protozoan inhabitant of dung.—After Dobell.

a., Active individual, found in moist dung of various animals; *b.*, such an individual in binary fission; *c.*, two individuals in conjugation, which usually takes place when the dung is passing into a condition in which it is no longer suitable for the *Copromonas*; *d.*, the zygote, encysted. In this condition it remains until it is swallowed by an animal, through whose intestine it passes, to become active in the dung.

kinds, protozoa, and bacteria are among the organisms which do in the destruction of such matter work similar to that which is done by the various corpse-feeding scavengers. The larvæ of the House fly,

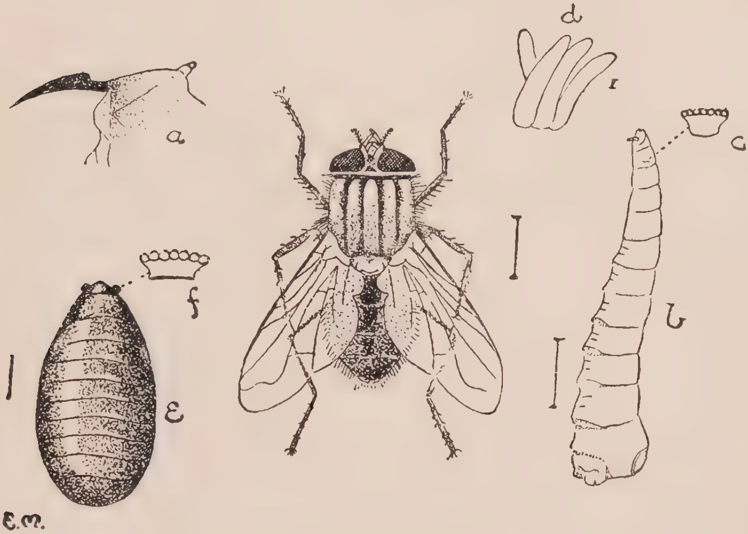


FIG. 12.—The life-history of the House fly (*Musca domestica*).—From Theobald.

a., Mandible of larva with adjacent structures ; *b.*, larva ; *c.*, anterior spiracle of the same ; *d.*, eggs ; *e.*, pupa case ; *f.*, remnants of spiracle on the same.

which feed either upon dung or upon matter which is rotting but has not passed through the body of an animal, are an example of organisms which are common to the two sets of scavengers. Many of the smaller members of each set pass the interval between opportunities of feeding in an encysted state, like that in which various aquatic animals survive periods of drought or frost (p. 247). Finally, sundry animals which, like the larvæ of fleas, find their food in dust, or, like earthworms, brittle-stars, etc., obtain nourishment by swallowing soil, mud, or sand, destroy the scattered remains of organisms as well as the living eggs, spores, etc., which the swallowed matter contains.

FIG. 13.—The larva of a flea in its natural surroundings.—After Bacot, from the *Journ. of Hygiene.* (Photo by Tonge.)

Organisms which are nourished after the manner of green plants, absorbing inorganic compounds, forming by photosynthesis carbohydrates, and building up proteins from these with elements obtained in inorganic salts, are said to be *holophytic*. Those which absorb from solution organic compounds that result from the partial decomposition of other organisms are *saprophytic*. Those which swallow complex and usually solid substances obtained from the bodies of other organisms are *holozoic*.

So much, from a general point of view, on the parts played by plants and animals in the economy of Nature. We are not in this book concerned to inquire further into the relations of plants with their surroundings. Henceforth we shall deal only with animals.

CHAPTER II

PHYSICAL FACTORS IN THE SURROUNDINGS WHICH AFFECT THE LIVES OF ANIMALS

THE innumerable circumstances which, in any locality, animals must cope with in their struggle for existence, and to which, accordingly, their organization is found to be adapted, may be classed under four or five heads.[1] There are :

1. those which arise from the nature of the *medium* (air or water) by which the animals are surrounded ;
2. those which arise from the nature of the *ground or substratum* (if any) with which the animals are in contact or in relation ;
3. those which arise from the amounts of *heat and light* which reach the place ; and
4. those which arise from the presence of *other organisms* in the neighbourhood of each animal.

To these, as we shall see, there should perhaps be added :

5. the *size of the space* through which extend continuously the conditions under which they are living.

In these circumstances, animals preserve and increase themselves and their race by an immense variety of appropriate action. In so far as the circumstances are favourable they exploit them, taking food, etc., in various suitable ways. Against the factors of their surroundings, whether living or lifeless, that are adverse, they make use of a series of expedients which, as we may note at the outset of our examination of them, are of three kinds. (i) They may flee, and thus remove to a less dangerous spot. (ii) They, or the race in the persons of their offspring, may stand their ground, relying either upon one or other of the innumerable kinds of armour and non-conducting or impermeable coats with which animals are protected, or upon one of the

[1] Logically it would perhaps have been correct to have included under a separate heading circumstances which arise from the periodicity of certain conditions, as light, heat, moisture, pressure, etc. But since the first two of these conditions are the most important and (except the tides) all the others depend upon them, we shall consider periodicity with light and heat.

equally numerous kinds of burrows, houses, and nests in which, as we shall see, they shelter themselves and their young. If this survival by endurance under shelter be achieved by the formation of thick-shelled eggs or cysts, it is often preceded by an act of sexual reproduction in species which do not reproduce thus in other circumstances. (iii) They may maintain themselves without such aid by chemical or mechanical action, warming

Fig. 14.—The nest of the Harvest Mouse.

themselves by internal combustion, fighting or poisoning their enemies, and so forth. Often an organ or an action may serve more than one end—as teeth may be used both for fighting and for devouring food, or a current may be set up which serves both for feeding and for respiration.

In later chapters we shall consider what actual contentions of circumstances animals have to meet in various localities, and how they are adapted to cope with them. Here we have to discuss the ways in which it is possible for the surroundings to affect animals.

1. *The medium* is the most important factor in the surroundings of an animal. Meeting all parts of the surface of objects that it contains, it exerts everywhere a pressure upon them, affects their movements, and controls all exchange, whether of matter or of energy, between them and the world about them; and from it animals directly obtain their supplies of oxygen, often of water, and even sometimes of food. It may be liquid or gaseous. It is either air, whose composition does not vary greatly except where by respiration animals alter it in their immediate neighbourhood; or a watery solution, whose composition varies a great deal, both in solids—in which it ranges from that of rain water to that of brine or the internal fluids of animals in which parasites are living —and also in the amounts of oxygen and carbon dioxide which it holds in solution. It varies in density and in viscosity with locality, from mountain air to water which contains much of solids in solution, and also in these respects with temperature. It varies, of course, in permeability to light and heat. Often it is in motion, and the motion varies greatly both in kind and in violence.

The medium affects animal life in a number of ways. (i) Some of these are *mechanical* results of its density and viscosity. Thus (*a*) it gives, according to its density, a varying amount of support to the body. By this it decides the shape that is possible with a given rigidity of tissues—as, for instance, a soft animal could not remain erect in air. That this support is not a crushing pressure is due to the fact that the body of an animal is permeated with liquid which is virtually incompressible; but when the body contains gases, as in lungs and the air-bladders of fishes, changes in the pressure upon it may bring about serious disturbances of respiration or by sudden expansion of the gases disrupt tissues and organs, and thus the medium limits the freedom of an animal to change the height or depth at which it lives. (*b*) It affects the possibility of the suspension of a body of a given weight, and thus the floating, swimming, or flying of animals, and also the amount of suspended matter by which they may be surrounded, which is of great importance, because such matter may include food, or the eggs or young of the animals, or particles of mud or dust by which they are liable to be smothered. (*c*) It offers to organs of locomotion the purchase which is necessary for their working, and its variation in this respect affects the amount of power which is required to make them effective. (*d*) On the other hand, it offers a varying amount of resistance to the passage of a body through it, and to efforts to draw it through cavities of the body, and thus also it affects locomotion and respiration. (*e*) Again, by the currents which flow in it, it

tends to move its inhabitants and to carry to and from them lighter bodies suspended in it; and also to limit, for plant-like creatures, the power of growth in certain directions, so that it affects the shape that they can assume in any locality. (*f*) Lastly, if it be liquid, it is often liable to freeze, and thus to limit or prevent the movement of animals in it; or to evaporate, and thus to abandon them to a medium of a different nature.

(ii) Another kind of influence of the medium is *due to its varying permeability to light and heat.* That, of course, depends upon its state, and upon the amount of matter which it may hold in suspension. We shall return to this question later on. (iii) The medium has also certain features which *by the process of diffusion* tend to affect the exchange of materials between the body of an animal and its surroundings. Thus (*a*) if the medium be liquid, according to its saline contents water and salts will tend to pass to and from the body of any animal which is not covered with an impermeable cuticle. This exchange is controlled by a special power possessed by the surface layer of protoplasm—which either is, or, owing to surface tension, behaves as, a delicate membrane—of regulating to some extent the passage of substances through itself; but it is of much importance both as facilitating excretion and the intake of certain salts, and as a danger when the accustomed salinity is changed or poisons are present. (*b*) If the medium be gaseous, according to the amount of water vapour it contains, water will tend to evaporate to it from the surface of the body. This is important owing to the necessity for the intake of water to compensate for it, and from its bearing on the regulation of temperature. (*c*) Whether it be liquid or gaseous, the medium offers, according to the gases it contains, varying possibilities of interchange of oxygen and carbon dioxide with the body. This has, of course, extremely important effects on respiration. (*d*) All these effects will be increased if currents, or the movements of the animal, bring new portions of the medium into contact with the body; and by the same means, in a liquid medium, poisonous excreta can be swept away.

2. The relation of animals to a *substratum* is less inevitable than that to a medium. Not every animal has a substratum; and the substratum with which an animal may be in relation is not necessarily one that is shared by the majority of other animals in its neighbourhood. Thus, the surface waters of the open sea are often a mile or more above the bottom, and constitute an independent region which as a whole is without substratum, yet for those of its smaller inhabitants that, by the property known as "thigmotaxis,"

are attracted to solid surfaces, a substratum exists in any large object in their neighbourhood, such as driftweed or the bodies of other animals; and, conversely, in the smallest pond there are animals living in the upper layers for whom the substratum does not exist. Again, a zoophyte rooted upon the back, say, of a crab is very differently circumstanced from one that grows upon a rock. Its substratum has a peculiar texture, moves, is liable to be shed by the crab and to break up, or to be devoured by enemies of the crab, keeps the zoophyte in the neighbourhood of the excreta and fragments of the food of its carrier, and so forth. So also an animal that dwells upon the branches of a plant has a substratum with many pecularities of its own. An animal may be in relation to a substratum without actually living in contact with it, if, for instance, it receive food directly or indirectly from it, or escape observation against it as a background, or be liable to be captured by animals living on it. It should be noted that the substratum does not become a medium to a burrowing animal, because such an animal is always bathed by a layer, however thin, of the true medium.

To those animals which are intimately associated with a substratum it serves: (*a*) to afford the necessary purchase to organs of locomotion in crawling, walking, and clambering, as the medium does in swimming and flying; (*b*) to enable sessile animals to root; (*c*) as a shelter to those that burrow in it; (*d*) as a source of nourishment to those that, like earthworms, swallow it for the sake of the organisms or organic débris that it may contain, or that, like various parasites and wood-boring animals, devour and digest it.[1]

3. *The temperature and illumination* at any spot are determined by many factors. The only important source of light is the sun, for the phosphorescence of organisms, though it is not without its functions in the economy of Nature, is in a broad view negligible. But the heat produced in animal bodies is very considerable, and must be taken into account. The influence of the medium upon light and temperature has already been mentioned. For reasons that will be stated later (p. 179), the temperature varies much more rapidly and within much wider limits where air is the medium than in water. Temperatures in the sea vary, according to season and locality, from $-2{\cdot}8°$ C. to $31°$ C., but those on land vary from $-65{\cdot}5°$ C. to $65°$ C. On the other hand, bodies in air may be protected to some extent from the effects of a rapid rise in temperature by the absorption of heat in evaporation from their surfaces.

[1] About burrowing animals something further is said on p. 89.

Illumination is also more intense, for a given amount of sunlight, in air than in water, both because air is more permeable, and because it has usually less matter in suspension. Other factors which affect temperature and illumination are shade, latitude, weather, and the conditions under which a parasite lives in the body of its host, which may be opaque or translucent, and have "cold" or warm blood. Lastly, it is an extremely important fact that, on land, between tidemarks, and to a less extent in shallow waters, light and temperature vary periodically with the season and time of day (and in places with the tides).

Noting, then, that light and temperature vary, not only from place to place, but in most places also from time to time, we may proceed to consider what are the relations of animals to them. That these relations are exceedingly important is obvious from many well-known facts, such as the difference between the animals of the tropics and those of temperate and cold climates. The wealth and beauty of tropical life are proverbial. Broadly speaking, except in special circumstances, such as those of deserts, tropical animals, alike on land and in water, are more numerous in species (though not in individuals), more brightly coloured, and larger than related inhabitants of localities which receive less heat and light. Here, however, our primary concern is not with the general connection between the nature of the animals that inhabit a locality and the temperature and illumination that prevail there, but with the more intimate relation of the life of the individual to those circumstances. This may be seen in various familiar facts, and notably in that the periodicity of light and heat, with that which it causes in the condition of the atmosphere in respect of moisture, and sometimes in the pressure and movements of the medium, imposes upon the physiology of animals rhythmical changes which are most conspicuous in such phenomena as sleep, breeding seasons, and occasionally hibernation, but affect also other functions. A rhythm of this kind may be so deeply impressed upon the organism as to continue for a time when the periodical changes which caused it have ceased. Thus the prawn *Hippolyte varians*, which normally changes its colour as the light grows and wanes every day, has been found to maintain this habit when it is kept constantly in the light or dark, and artificial illumination does not prevent the need for sleep from recurring in Man at intervals which roughly correspond to the length of a day. Seasonal periodicity in the physical conditions of life, and the corresponding physiological periodicity of animals, are of little importance in the tropics, and are absent, with the daily periodicity, in the deep sea and in caves.

In detail, the relations of animal life to temperature and to light must be considered separately.

We have already alluded to the effects of *temperature* on life, and have seen that the chemical processes of living beings, like other such processes, vary with the temperature, being slowed as the protoplasm becomes colder and quickened when it is warmed,[1] but that they are brought finally to an end when its microscopic organization is destroyed either by the coagulation of certain of its proteins by heat or by the freezing of its water. The points on the thermometer at which these things happen vary in different animals with the composition of the protoplasm. The point at which protoplasm is killed by heat appears to be higher in protozoa, where it is said to reach 55° C., than in metazoa, where it is about 45° C. That at which cold directly causes death is less accurately known, but is always below the freezing-point of pure water, on account of the presence of substances in solution in the water of protoplasm. To be effective, these temperatures must, of course, take effect not merely on the exterior of the body, or even on the unessential parts of its tissues, but on the protoplasm itself. Thus various fishes, frogs, snails, centipedes and other "cold-blooded" animals may be cooled till they are not only apparently dead, but even frozen stiff, and yet recover when they are slowly thawed, presumably because their protoplasm is so organized that its structure is not destroyed when it solidifies. This also illustrates the way in which life can be slowed and temporarily stopped by cold. The same thing is seen in the gradual slowing down of the activity of infusoria, which is brought about by a lowering of the temperature of the water in which they are living. The contractile vacuoles work more and more slowly, and finally both their working and that of the cilia stops until the temperature be raised. A similar numbing effect of cold upon insects is well known. The artificial suspension of life in tissues by low temperature has been made use of in surgical operations even on warm-blooded animals, portions of living tissue removed from one body being preserved for days in a state of suspended vitality and afterwards successfully grafted in to repair injuries in another body. In this way, for example, the cornea taken from an eye that had for some other reason been removed from a human patient has been used after several days to replace the same tissue in another man in whom it had been injured.

[1] It should, however, be noted that many vital processes (the rate of development of eggs, beat of the heart, etc.), though they are hastened by a rise of temperature, do not follow ordinary chemical laws in respect of their temperature coefficients.

These cases are, of course, equally illustrative of the quickening of the processes of life by warmth. Further illustrations of the same thing are seen in the well-known effect of warmth on sexual activity and on the development of the eggs of animals of all classes; and by comparing the rates of metabolism, as shown by the output and intake of the gases of respiration, in warm and cool water, it has been shown that the life of various marine organisms (as, for instance, the sea cucumber *Cucumaria*) is more vigorous at a high temperature. When the temperature becomes too high there is often at first a feverish activity in animals, and in some cases there has been observed an output of nitrogenous excreta which shows that proteins are being used up at an excessive rate. Afterwards, for some reason that is not clear, perhaps because of the formation of poisonous products in the body, a condition of heat-coma comes on before death. Heat is more injurious to the individual animal than cold. Not only is the point at which it becomes fatal by destroying the protoplasm more quickly reached, but, what in practice is more important, before that limit is reached it is injuriously stimulating, while cold merely suspends or lessens activity. This is why individual animals from warm climates are usually less susceptible to cold than cold-bred animals are to warmth. But upon the race the result of change of temperature is different, because under the depressing influence of cold a warm-bred animal does not reproduce its kind, whereas a cold-bred animal, if it survive long enough, is stimulated by warmth to breed, and the species has thus a chance of establishing itself in the new climate.

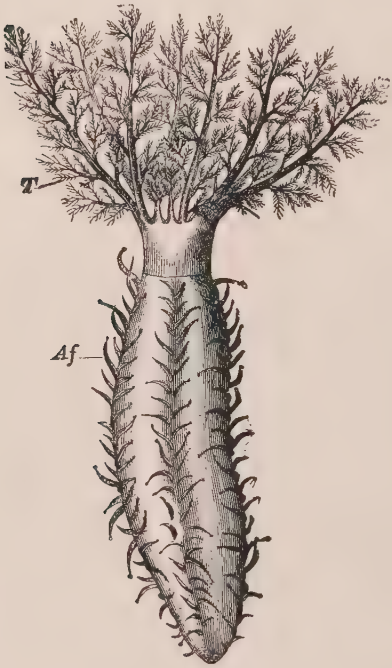


FIG. 15.—The sea cucumber *Cucumaria*. —From Sedgwick.

Af., Tube feet; *T.*, tentacles. The tentacles are sticky, and, when small organisms are adhering to them, are placed in the mouth and stripped as they are withdrawn.

Between the points at which heat and cold become injurious, there is for every animal an optimum range of temperature of body

FIG. 16.—The Puma.—After Elliott.
Note that the cubs are spotted, though the adult is self-coloured.

within which the life-processes are adjusted to proceed smoothly, and which actually prevails in it for the greater part of its life. In most animals it is at least as great as the normal range of tem-

perature of the surroundings, either during the whole year or during the season of their activity,[1] and in such animals the internal temperature is by conduction kept in correspondence with the external; but this is not true of the "warm-blooded" animals, which, as we shall see, maintain an almost constant optimum internal temperature of their own. Yet these also are adversely affected by too great an alteration in the external temperature, which over-

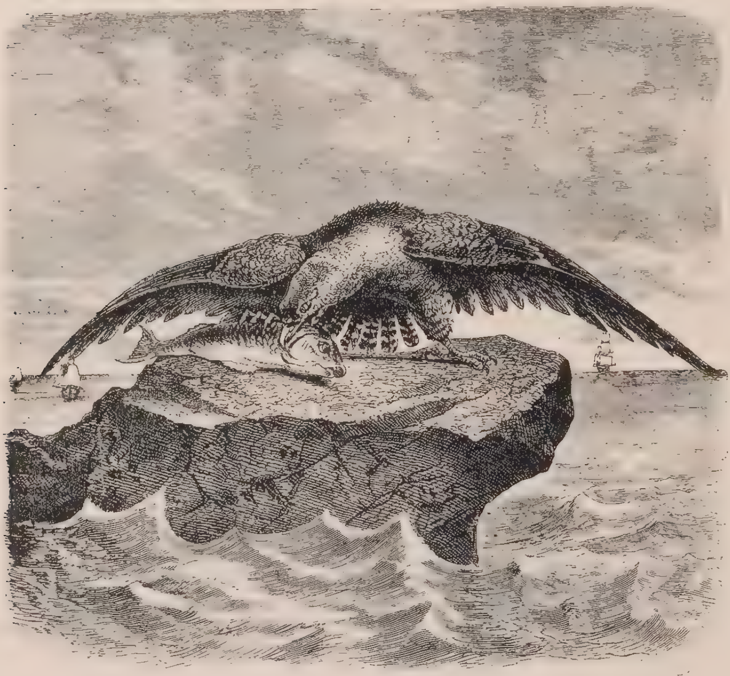


FIG. 17.—The Osprey.—From *Cassell's Natural History.*

taxes or overrides the heat-regulating mechanism. Thus every animal has an optimum range of external as well as one of internal temperature, and these may coincide or the latter of them may be the narrower. The limits within which the temperature of the surroundings can vary without injurious effects differ greatly in different animals, even when they live in the same locality. Those which can endure a great variation in external temperature are

[1] Many insects, for instance, are killed by the external temperature falling below their limit in the autumn.

said to be *eurythermal*; those in which the optimum range of temperature is narrow are *stenothermal.* Land animals, as a rule, are more eurythermal than those of the water.[1] As examples of highly eurythermal animals we may cite the Puma, which is at home in every climate from Patagonia to Canada, and the Osprey, which ranges over the greater part of all the continents. The Wall Lizard (*Lacerta muralis*) is found from Belgium to North Africa, the Grass Snake (*Tropidonotus natrix*) from Sweden to Algeria, and the Common Toad (*Bufo vulgaris*) from Trondhjem to Morocco. Sinclair speaks of finding in the island of Cyprus some species of centipedes equally lively on the burning plains and in the snow on the mountains. The Common Eel of Europe is found from Iceland to the Nile; but, of course, the range of temperature is not so great in water as in air. The Brine Shrimp (*Artemia salina*) thrives in salt marshes of North Europe and in shallow pans exposed to the full rays of the South European sun for the purpose of evaporating the water to obtain salt. Stenothermal animals may need warmth, in which case they are said to be *thermophile*, or coolness, when they are *psychrophile.* Any zoological garden provides many examples of thermophile animals, whose cages must be warmed. Coral reefs are found only in warm seas because the species of zoophytes which build them cannot exist elsewhere. The Carp is a familiar example from fresh water. The sensitiveness of the Goldfish to temperature is well known. Carp will only feed between 9° C. and 30° C., and their absolute optimum is at

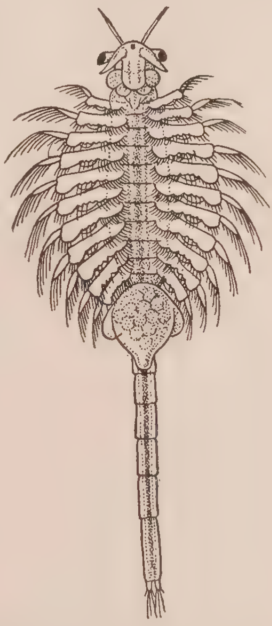


FIG. 18.—The Brine-shrimp, (*Artemia salina*).—From Calman.

[1] It should be noted that this refers to the external range of temperature, and does not necessarily imply that in warm-blooded animals the *protoplasm* is eurythermal. Excepting those that hibernate, it is probably true to say that the protoplasm of all such animals is stenothermal. Thus the rabbit, whose normal temperature of about 39° C. is maintained by the heat-regulating mechanism through a range of external temperature from many degrees below freezing-point to 45° C. (for a short time—the rabbit sweats little if at all, which accounts for this low figure), dies if by the failure of that mechanism the internal temperature fall to 18° C. or rise to 44° C.

25° C. An extreme case is that of the fauna of certain hot springs, consisting of crustaceans, insect larvæ, etc., which live at a temperature of 50° C. to 60° C., though how they are enabled to do so is unknown. Examples of psychrophile animals are the Trout, which thrives between 2° C. and 20° C. and spawns in October and November, the Glass Snails (*Vitrina*), the freshwater crustacean *Lepidurus glacialis*, found in Arctic and subarctic countries only, and, most remarkable of all, the invertebrate fauna of snowfields (p. 303). Within the optimum range of temperature there is doubtless often or always an absolute optimum, but, as a rule, provided that the temperature be within that range, it is more important for an animal that it should remain fairly constant than that it should stand at any particular point. It is for this reason, as well as on account of the absolute limits that temperature sets, that the distribution of animals is governed more by the extremes of temperature and by its constancy in various localities than by their mean temperatures.

FIG. 19.—The glass snail (*Vitrina pellucida*).

The effects of low and high temperatures are guarded against by animals in different ways. (*a*) Probably in all cases a certain amount of heat is produced by the chemical changes of life, partic-

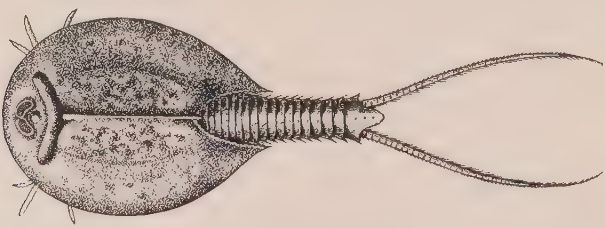


FIG. 20.—*Lepidurus glacialis.*—After Sars.

ularly in those which lead to movement (contraction), and this must make it less easy for cold to affect the protoplasm, though in most instances its effect is not very far-reaching. (*b*) The eggs, spores, and similar bodies of many organisms can stand prolonged exposure to very much higher or lower temperatures than those which will

kill ordinary protoplasm. This is perhaps because they contain relatively little water, so that on the one hand they are hard to freeze, or on the other their proteins are not in a condition of solution in which they are easily coagulated by heat. It is not confined to the animal kingdom, and indeed is probably best seen in the spores of bacteria, which can be subjected to the greatest extremes of low temperature, and must be kept for some time at 180° C. if they are to be destroyed by heat. The eggs of silkworms and other insects may be exposed for a long time to temperatures of − 20° C. and − 30° C. and yet develop when they are removed to warm surroundings; and many small freshwater animals give rise to eggs and other reproductive bodies which will live though their surroundings be frozen or exposed as dry mud to the baking heat of the sun. (*c*) In the most highly organized animals, mammals and birds, the heat set free during the muscular and other chemical processes of life is very considerable, and there is a non-conducting covering of fur or feathers by which it is retained, and a nervous mechanism by which its production and loss is regulated, so that the temperature of the body is kept even and does not vary with that of the surroundings as it does in other organisms. Since this constant temperature is considerably above those which are common in their surroundings, these animals are known as "warm-blooded," while the others are "cold-blooded." Actually, however, the temperature of a "cold-blooded" animal is high when that of its surroundings is high, and the temperature of a "warm-blooded" animal may for a time be below that of its surroundings, so that these terms are not strictly correct, and the words "homoiothermic" (even-temperatured) and "poikilothermic" (variable-temperatured) are often substituted for them.

In regulating the temperature of the body, the nervous system of a warm-blooded animal uses two means: it varies the rate at which heat is produced in the body, and the rate at which it is lost from the surface exposed to the air by the skin and lungs. The production of heat is varied by increasing or diminishing the activity of the muscles. A certain amount of heat is produced by the muscles in maintaining their "tone" even when they are at rest, and this can be increased or diminished, and added to by active contraction, as in shivering. When the internal temperature rises, the flow of blood to the skin is increased, and the animal may pant, so as more rapidly to change the air in the lungs.[1] Loss of

[1] Panting is, of course, also used as a remedy for insufficient oxygenation of the blood.

heat from the exposed surfaces takes place by radiation, conduction, and convection,[1] and sometimes also by evaporation : conduction is of more importance in water and radiation in air, and it is only in air that evaporation can come into play. There must always be some loss by evaporation in the lungs, but it is only in mammals, which possess sweat glands,[2] that this mode of cooling becomes of importance. Like the blood flow, the secretion of sweat is under the control of the nervous system. When the amount of sweat is small it evaporates so quickly as to be unnoticed, and the process is called "insensible" perspiration : when the amount formed is increased or its immediate evaporation is prevented, it becomes visible as "sensible" perspiration. The loss of heat by evaporation is of great importance in enabling animals to live for a time in surroundings which are at a temperature that would otherwise be fatal. Human beings have been known to bear without injury for several minutes a dry temperature of 130° C. Naturally, a moist heat is less easily borne than a dry one, since it offers less possibility of evaporation. The average temperature of mammals is about 39° C. That of Man is about 37° C. That of the primitive Duck-mole (*Ornithorhynchus*, Fig. 379) and Spiny Ant-eater (*Echidna*) is about 25° C. and is much more variable than that of other members of the class. The average temperature of birds is about five degrees higher than that of mammals. The temperature of cold-blooded animals is often a fraction of a degree above that of the medium in which they are living, and sometimes during muscular exertion it may rise several degrees. In a few cases, as in bees in the hive, and the female python, which incubates her eggs, it may be maintained for a long time a number of degrees above that of the surroundings. On the other hand, when evaporation can take place, as in frogs, it may at times be less than that of the air. (*d*) Certain animals, as winter approaches, *hibernate*, that is, retire to burrows or other shelter, where they lose less heat, and, since then they cannot feed, fall into a torpid state, so that their expenditure of energy upon work is reduced to a minimum. All the activities of their bodies, including respiration and the heart beat, are greatly lessened, and the temperature of warm-blooded animals falls to a point little above that of their surroundings. Hibernation is

[1] Heat is transmitted by convection when material particles conveying the heat are carried from one point to another—*i.e.* by currents in the fluid medium.

[2] Whales and dolphins, mammals which are purely aquatic and have therefore no use for sweat glands, do not possess them, and they are also lacking, or ill-developed, in moles, various rodents, etc., whose habits, perhaps, do not call for sudden regulation of temperature.

known to happen in various classes of animals—mammals (as the Squirrel, Marmot, Dormouse, Bat, Hedgehog, etc.), reptiles, amphibians, insects, molluscs, etc. Sometimes, as by squirrels, a store of food is laid up, and consumed when the animal awakes at intervals. Other animals fatten before they retire. The Dormouse does both these things. In the Frog the fat bodies (Figs. 183, 184) appear to serve principally for the ripening of the testes or ovaries in the spring. The temperature of a mammal rises extraordinarily rapidly when the animal awakes. In the Dormouse it may increase by 20° C. in an hour. Other animals, especially in warm climates, sleep during the summer, but this is probably often a precaution against drought rather than heat.

Besides the fundamental influence on the functioning of protoplasm by which it determines the possibility of life for any animal, and imposes the necessity for a series of adaptations to meet it, temperature has upon various organisms effects by which it produces in individuals superficial bodily changes. These may be adaptive, as when cold causes fur to become thicker, but often appear to be, in a sense, accidental, and to have no relation to the struggle for existence. Thus heat and cold applied to the pupæ of certain Butterflies bring about differences of colouring in the imago, and it is possible in this way to produce, not only members of races which inhabit the warmer and cooler parts of the range of a species, and of broods, such as those which we shall presently mention, which appear at different seasons, but even forms which do not occur in Nature. Again, it has been shown that if the eggs of the sea-urchin *Strongylocentrotus lividus* be placed in water at 8° C. or 25° C. for even a minute at the time of impregnation, the resulting larvæ after eight days' development are some 4·4 per cent. smaller than those developed from eggs which were impregnated at from 17° C. to 22° C.

Animals are, of course, also affected by the temperature of their surroundings indirectly, in the effect which it has upon the vegetation which provides their food.

Thus the temperature of any locality has in three ways a part in determining the kinds of animals that live there: (*a*) occasionally, by a direct effect in altering individuals in the course of their lives; (*b*) universally, but more indirectly, by imposing limits within which they must be able to live; (*c*) also universally, but still more indirectly, by affecting the vegetation. In many parts of the world these effects of temperature are seen both in the permanent composition of the fauna and in its seasonal changes, which depend on variations of the temperature with the time of year. Seasonal changes in

temperature may (*a*) produce seasonal broods, as in the Green-veined White Butterfly (*Pieris napi*), whose dusky spring generation differs from that of the summer, and the more striking instance of the continental *Araschnia levana*, whose two broods were formerly regarded as distinct species (*A. levana* and *A. prorsa*) ; or (*b*) bring about migration, or winter or summer retirement ; or (*c*) kill off the adults of a species, in which case its reappearance in the next year may be due either to survival of the eggs, owing to a protective

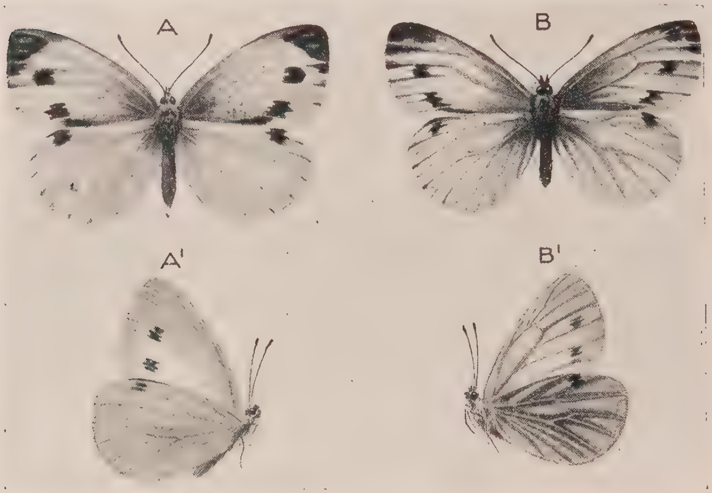


FIG. 21.—The Green-veined White butterfly (*Pieris napi*).
A., *A'.*, The summer brood ; *B.*, *B'.*, the spring brood.

covering or more eurythermal protoplasm, or to immigration from outside, when the temperature is more favourable.

Indirectly, the presence or absence of *light* in any locality affects very powerfully the animals which live in it, by determining whether plants can grow there, and thus the kind and quantity of food that will be available. Directly, it is of much less importance than the temperature, yet has certain consequences. (*a*) Light makes available for animals another sense by which to explore their surroundings. In most cases this is useful for the information which it gives concerning food and enemies : only in the higher animals it is used in mating. To take advantage of it, it is not always necessary that an animal should possess eyes or similar organs. In many of the lower animals (*Amœba*, *Hydra*, the Earthworm, etc.) the protoplasm, or some part of it, is sensitive to

light without any evident organization to that end. Since light, to produce effects, must be absorbed, there must be some substance present in these cases to absorb it. Generally, however, animals that are sensitive to light possess pigmented organs in which it is absorbed and its energy transmitted as a stimulus to the protoplasm. Such organs, as is well known, vary from the speck of red pigment found in many protozoa to the complicated eye of the vertebrata. Only when there is a well-organized eye with a lens or lenses can the shape of objects be perceived. In other cases all that is appreciated is the presence or absence of light. Yet even this sense is exceedingly valuable. By it an animal that either feeds on vegetable organisms or possesses symbiotic algæ (p. 60) can discover where plant life is possible. By it the regions where light will enable a more highly organized foe to search for prey may be avoided. By its aid shells can be closed and burrows entered when the shadow of an approaching enemy falls. Animals that are sensitive to light not only regulate in these ways their actions from moment to moment, but exhibit periodical alternations of activity with rest or sleep, in light or darkness, according to their needs and the habits of their enemies. (*b*) It is very probable that chemical reactions are caused by light to take place in the bodies of certain animals. Thus from observations upon children suffering from rickets it has been inferred that sunlight causes the formation in the body either of " vitamin A " (p. 55), or of some compound which can take the place of that substance in curing the disease. In this case, at least, the direct action of light is of very great importance in the physiology of an animal organism. But, of course, there are many animals for which it would be impossible, on account either of their habits or of the covering of their bodies. (*c*) The pigment of eyes is perhaps only a special case of a general tendency of light to induce pigmentation of those surfaces of animals upon which it falls.

That the connection between light and pigmentation is not an inevitable one is shown by the pigmentation, in certain animals, of organs which are shielded from the light, such as the peritoneum and the lining of the mouth, and the presence in the blood of the pigment hæmoglobin, and conversely by the complete absence of pigment from the skin of a few animals which live in strong light. But, on the other hand, pigmentation is rare in internal organs, and is only lacking from the surface of the body in exceptional cases, namely, (i) in certain pelagic animals whose whole body has for some reason developed an extreme transparency; (ii) in a few inhabitants of cold climates which are obviously adapted

by their whiteness to the snowy surroundings in which they live; (iii) in a number of animals, such as internal parasites and some inhabitants of dark caves, like the Olm (*Proteus*), which are not exposed to light; and (iv) on the under surface of other animals which, like the belly of most vertebrates and the lower side of flat fish, is partly shielded from the light and is pale or quite white. There are, moreover, many facts which show that light has a direct effect upon the pigmentation of the individual. It has been found in various instances (frogs, newts, the eye of water-fleas, etc.) that the absence of light during development hinders the establish-

FIG. 22.—The Olm (*Proteus anguineus*.—From Brehm.

A blind, white newt, found only in certain underground waters of South-Eastern Europe.

ment of pigmentation; and, conversely, a very interesting series of experiments by Cunningham has established that young flounders kept in tanks under such conditions that their lower surface can be artificially illuminated by means of mirrors, develop pigment on both sides. It has also been found that if *Proteus* be kept in the light it will in a few months turn quite black; and the bronzing effect of strong sunlight upon the human skin is well known. Thus it is clear that some connection exists between light and pigmentation. But the nature of the connection is less clear. The actual pattern is probably nearly always adaptive—tends, for instance, to conceal the animal in its natural surroundings or,

by making a poisonous creature conspicuous, to cause others to beware of molesting it—and is no doubt established as other adaptive characters are, whether that be by natural selection or in some other way. Yet it is hard to avoid the conclusion that so general a phenomenon is based upon a general property of laying down pigment in response to the stimulus of light. Whether this also be in the long run adaptive, to the end, perhaps, of shielding the body from some rays in the light which are injurious, is another question.

4. Here attention may conveniently be called to the fact that the physical conditions in any locality affect an animal that dwells there, not only in the direct ways which have just been stated, but also indirectly through the *other organisms* whose existence they permit. To take obvious instances, a herbivorous diet is only possible where plants can grow, a parasite can exist only in a locality which is suited to the life of its host, and the habit of sheltering among the stinging tentacles of a zoophyte can only be pursued where the conditions allow the zoophyte to live.

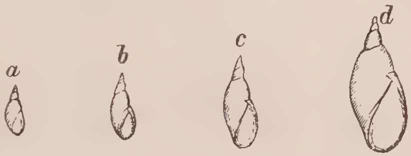


Fig. 23.—Four equally old shells of *Limnœa stagnalis* hatched from the same mass of ova, but reared in different volumes of water.—From Semper.

a., in 100 cubic centimetres; *b.*, in 250 c.c.; *c.*, in 600 c.c.; *d.*, in 2000 c.c.

5. The *size* of the continuous space through which extend the conditions which permit an animal to live probably affects it in more ways than one. (*a*) There is some reason to believe that both land and water animals bred in a confined space tend to be smaller than members of their own species raised where there are no such limits. This has been found to happen with hog-slaters (*Asellus*), water snails (*Limnœa*), and tadpoles, raised in small vessels; and the size of animals in land-locked seas and upon islands is often subject to some influence which at least produces a superficially similar result. (*b*) Besides this influence of area, which in the first instance at least is exercised upon the individual, there is another which concerns rather the race. Any pressure which the surroundings may be exerting upon a group of members of a species is intensified when they are isolated in a small area so that they can neither escape into nor be recruited from other parts of a wide range in which conditions vary. They are liable either to be exterminated or to give rise to a new race under the influence of the surroundings,[1] whether that be exercised directly or by selection.

[1] It is, of course, not inevitable that either of these things should happen.

Isolation is one of the most important factors in the origin of species, and it is those animals which are distributed in small colonies which are most fertile in local races, though, of course, it is necessary for the origin of these that the means of distribution from one colony to another should be limited. A few striking instances may be

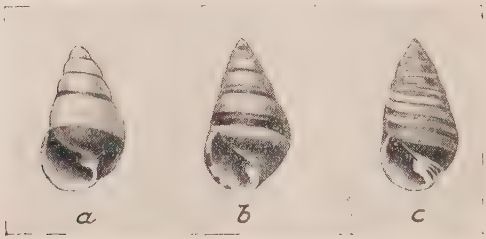


Fig. 24.—Species of *Achatinella*.—After Pilsbry.
a., *A. fulgens*; *b.*, *A. briddi*; *c.*, *A. phæozona*.

quoted. Speaking of the Snails, Cooke says: "Land mollusca are, as has been remarked, fettered to the soil. Quadrupeds, birds, fishes, and reptiles are provided with organs of motion which enable them to pass barriers of various kinds . . . but the mollusca have no such regular means of transport, and are, in a large number

Fig. 25.—The Loch Killin Charr (*Salmo killinensis*).—From Regan.

of instances, limited to districts of a certain character of soil, or producing certain kinds of vegetation. The genus *Achatinella*, which is peculiar to the Sandwich Islands, is found there in a profusion of species. It lives [on high ground] in the mountain valleys which radiate from the central ridge of each island, and each valley is characterized by its own particular set of species. . . . Extreme cases of

this restriction of habitat sometimes occur. Thus *Limnæa involuta* is found only in a single small mountain tarn in Ireland; *Clausilia scalaris* along a narrow strip of limestone in Malta ; *Strophia nana* is confined to a few square rods on an island that is itself a mere dot in the Caribbean Sea ; the genus *Camptonyx* occurs only in the neighbourhood of Mt. Girnar in Gujarat ; and *Lantria* in moss on the top of a mountain in Bourbon." The fishes of the Trout family (*Salmonidæ*) are another example of the effects of isolation. Scattered in pieces of inland water where conditions differ and opportunities of communication seldom or never occur, they have given rise to numerous local races, sometimes restricted, like the Loch Killin Charr (*Salmo killinensis*), to a single lake. A third instance is afforded by the family Drepanidæ, song-birds of Hawaii. Jordan and Kellog say of this family that " each of the Hawaiian Islands has its species . . . some green in colour, some yellow, some black, some scarlet, and some variegated with black, white, and golden. . . . On each island most of the species are confined to a small district, to a single kind of thicket or a single species of tree, each species being especially fitted to these localized surroundings. . . . In each of the several recognized genera there are numerous species, mostly thus specialized and localized."

CHAPTER III

ORGANISMS AS FACTORS IN THE SURROUNDINGS WHICH AFFECT THE LIVES OF ANIMALS: SPECIAL RELATIONS BETWEEN ANIMALS AND PLANTS

RELATIONS between an animal and other organisms in its surroundings are almost always based in the long run upon nutrition. Either such organisms serve the animal for food, or they attack it to make it their food, or they are competitors for a common food-supply, or in rarer cases they assist it, or obtain its assistance, in the quest for food or in defence against enemies which would use

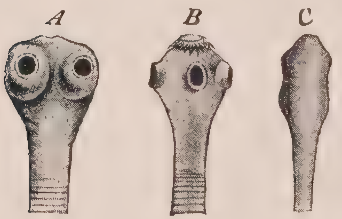


FIG. 26.—The heads of three tapeworms. Note the absence of mouth and presence of suckers and hooks for attachment. —From Lang.

A., *Tænia saginata*; B., *T. solium*; C., *Bothriocephalus latus.*

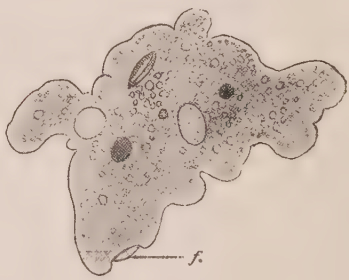


FIG. 27.—*Amœba proteus* in the act of feeding.

f., The small vegetable organism which is being swallowed.

it or them for food. Only between members of opposite sexes of the same species are there relations which are concerned not with food but with reproduction.

The food of every animal contains organic substances derived from the bodies of other organisms. Usually these substances are taken direct from a body, which may be living, or recently killed, or in process of decomposition; but some intestinal parasites obtain them after they have been digested by the host; and if Pütter be correct in his surmise (see p. 193), many marine animals

absorb from the water substances discharged into it by plants. The means that are used in taking food vary enormously. (*a*) In certain animals that are inhabitants of decaying matter or parasitic, such as "saprophytic" protozoa and the Tapeworms, it is absorbed through the surface of the body; and doubtless this was the primæval mode of nutrition. (*b*) Amœboid protozoa engulf food into their protoplasm. In all other animals there is a mouth. (*c*) This may suffice in itself, seizing the food either simply by muscular action, like that of the Earthworm, which easily passes into suction; or with the aid of teeth, as in various polychæte worms (Fig. 356), starfishes, sea-urchins, and vertebrates, and in

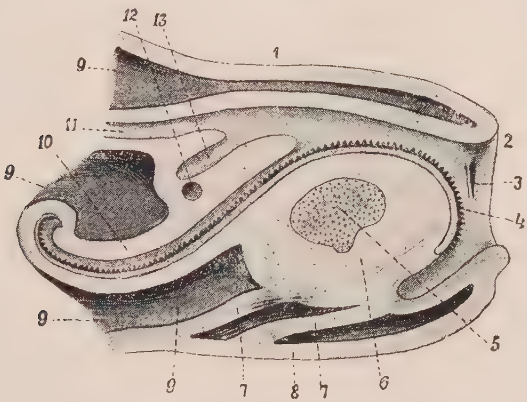


Fig. 28.—A diagram of a longitudinal section (not quite median) through the snout of a whelk.—From Lang.

1, Dorsal wall of the head; 2, mouth; 3, jaw; 4, radula; 5, lingual cartilage; 6, 7, muscles; 8, ventral wall of the head; 9, cavity of the head; 10, sheath of radula; 11, œsophagus; 12, opening of salivary duct; 13, infolding behind sheath of radula.

those molluscs which have a radula and jaws; or of some analogous apparatus, such as the fringe of frayed whalebone which in certain whales, hanging down from the upper jaw, strains out floating organisms from the water. Teeth, of course, are of various kinds. They may be horny (epidermic), as in molluscs, worms, lampreys, and tadpoles; or be calcareous structures of which the greater part at least belongs to the true skin (dermis), as in echinoderms and most vertebrates. Of whatever they be composed, their shape varies according to their function, which depends upon the diet. They may be conical or spine-like for seizing and holding the prey, as in the Frog and various fishes (Figs. 31, 243); or chisel-shaped, for cutting, like the front teeth of mammals; or broad and adapted for

crushing, like the cheek teeth of Man. Crushing teeth are often used also for grinding, but there is a special grinding type, found in various forms in different herbivorous mammals, in which the broad

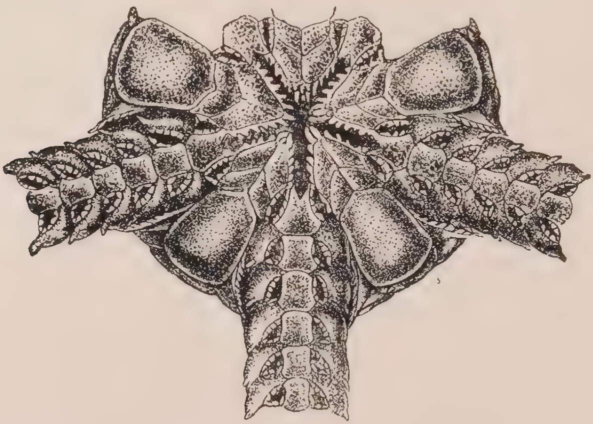


Fig. 29.—Part of the disc, and some of the joints of three arms, of *Ophioglypha bullata*, a brittle star.—From Shipley and MacBride, after Wyville Thomson.

Note the teeth around the mouth, and the elaborate skeleton of the arms, which are the organs of locomotion of the Brittle Stars.

crown bears a number of ridges, and is often composed of substances of different degrees of hardness which wear away at different rates

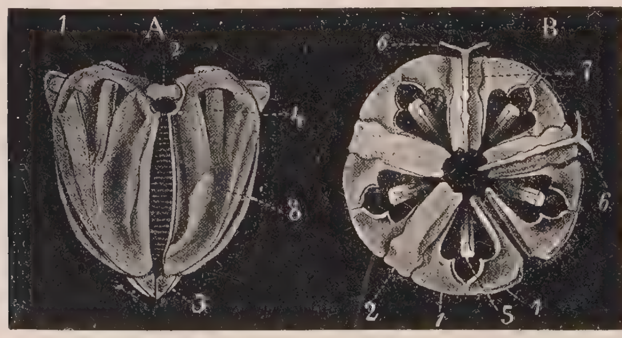


Fig. 30.—The teeth and jaws of a sea-urchin.—From Lang.

A., From the side; *B*., from above. 1, one of the five jaws; 2, an intermediate plate between two jaws; 3, the biting end of a tooth; 4, the middle part of a tooth; 5, the upper end of a tooth; 6, 7, two of the five "compasses" to which certain muscles are attached; 8, a jaw in side view. The whole apparatus is known as "Aristotle's lantern."

so that they keep their ridges as they are worn down. This arrangement is well seen, for instance, in horses. Sometimes a pair of teeth are developed into powerful tusks, and are used as weapons (p. 78). Usually the teeth of an animal, though they are not exactly alike, are all of one type, and can only deal with the food in one way; but in most mammals (though not, for instance, in toothed whales) they are of several kinds—a set of cutting teeth (incisors) at the front of the mouth, a pair of seizing teeth (canines), and a number of cheek teeth (premolars and molars) used for crushing, grinding, or tearing. Each of these sets differs, of course, according to the kind of food which the animal takes. Such

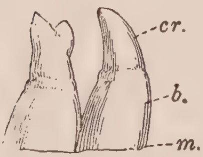


FIG. 31.—Two of the teeth of a frog.

b., Base of the tooth; *cr.*, crown; *m.*, edge of the maxilla.

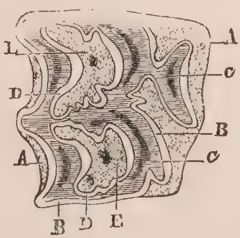


FIG. 32.—A transverse section of an upper molar tooth of a horse, showing the various substances of which it is composed.

A., External cement; *B.*, external enamel; *C.*, dentine; *D.*, internal enamel; *E.*, internal cement. The hard enamel wears down more slowly than the other parts.

mixed dentitions are also found in certain reptiles, fishes, and molluscs. Teeth are usually present on both jaws of a vertebrate animal, but they are sometimes lacking either on the lower jaw, as in the Common Frog, or on the upper, as in the Sperm Whale, or on both, as in birds, turtles, and the adult Duckmole (Fig. 379), where their place is taken by a horny covering. An arrangement for straining, other than the apparatus for that purpose, presently to be mentioned, which is found in various animals that feed by means of cilia, is possessed by many fishes in the form of "gill-rakers," which lie across the gill clefts, and by the Whalebone Whales in the frayed curtain of their mouths. Fishes in which this apparatus is well developed are, like the Whalebone Whales, feeders on the plankton (pp. 181, 190). (*d*) In many aquatic animals,

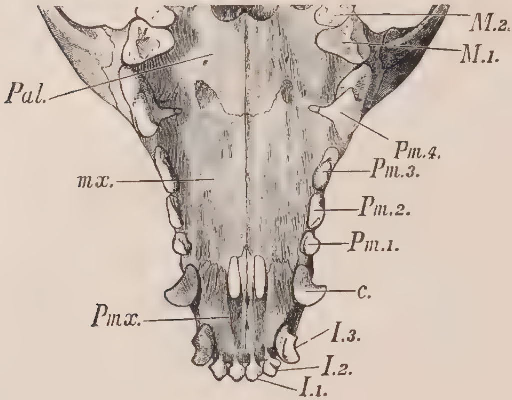


FIG. 33.—The bones of the palate and the upper permanent teeth of a dog.

c., Canine tooth ; *i.*, incisor teeth ; *M.*, molar teeth ; *mx.*, maxillary bone ; *Pal.*, palatine bone ; *Pm.*, premolar teeth ; *Pmx.*, premaxillary bone.

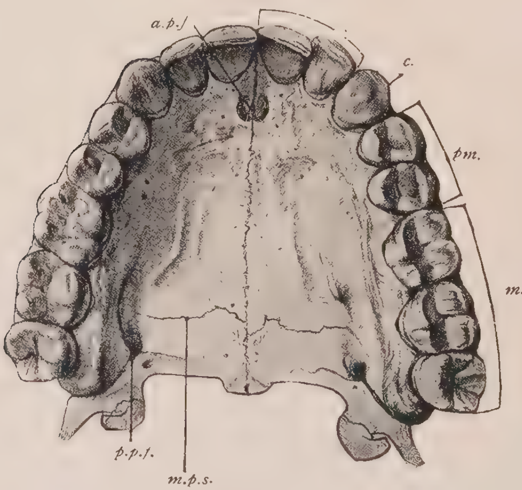


FIG. 34.—The bones of the palate and the upper permanent teeth of Man.

a.p.f., Anterior palatine foramen ; *c.*, canine tooth ; *i.*, incisor teeth ; *m.*, molar teeth ; *m.p.s.*, suture between maxillary and palatine bones ; *p.m.*, premolar teeth ; *p.p.f.*, posterior palatine foramen.

as in ciliate protozoa, such as *Paramecium* and *Vorticella*, the food is not seized by the mouth, but is swept to it by a ciliary apparatus; and this apparatus is sometimes raised upon lobes or arms, as in the Crinoids (Sea Lilies and Feather Stars), Polyzoa, Brachiopoda,

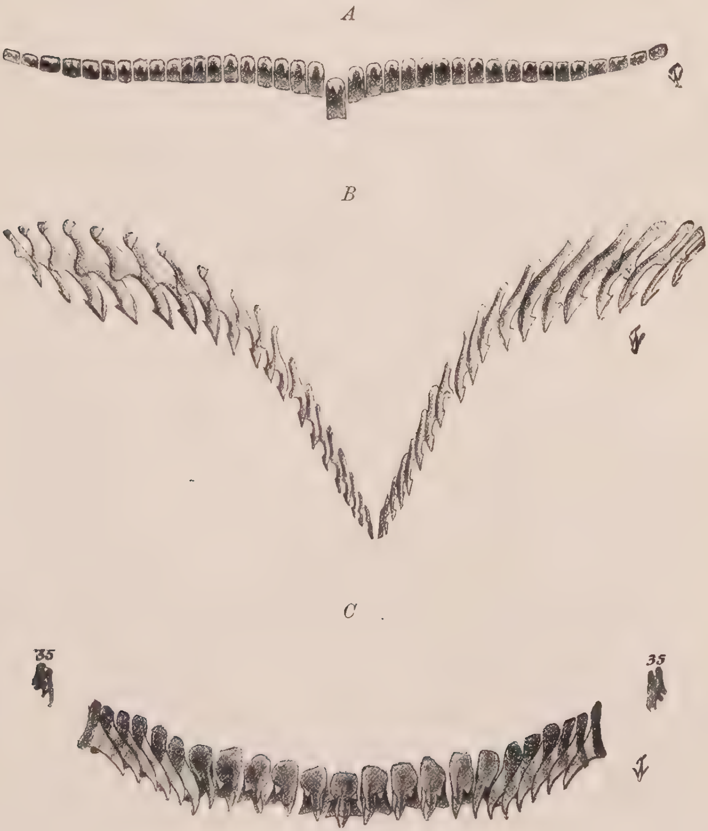


FIG. 35.—Transverse rows of teeth from the radulas of molluscs of different diet.—From Taylor.

A., *Helix pygmæa*, vegetarian; *B.*, *Testacella haliotidea*, carnivorous, feeding on earthworms; *C.*, *Hyalinia nitidula*, omnivorous, with carnivorous teeth at the sides, and others, adapted to a vegetarian diet, in the middle.

Pterobranchia, Rotifera, etc.; or has the form of a strainer of lattice-work over which streams a sticky mucus, as in ascidians (Fig. 236), and the Lancelet (*Amphioxus*), where the wall of the pharynx is the strainer, or bivalve molluscs, where the gills perform that function. In the Common Jelly-fish (*Aurelia*) (Fig. 217), and

probably in many others, practically the whole surface of the umbrella collects particles from the water, entangling them in mucus which by ciliary action is passed to the edge, where it is licked up

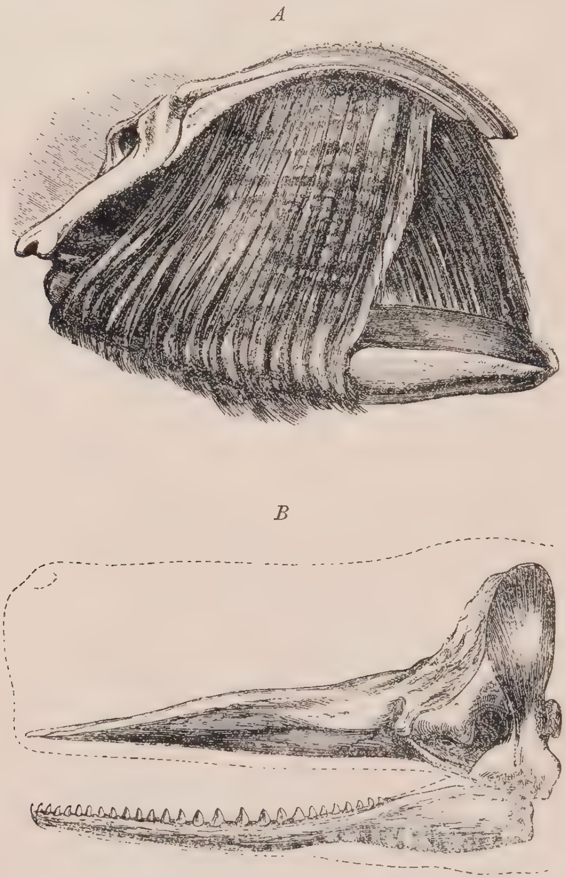


FIG. 36.—Skulls of two whales.

A., The Greenland Whale (*Balæna mysticetus*), a member of the Suborder Mystacoceti, which are without teeth and capture their food by means of a fringe of whalebone. In life the lower end of the fringe is tucked in between the tongue and the jaw. *B.*, The Sperm Whale (*Physeter macrocephalus*), one of the Odontoceti. The dotted line shows the outline of the soft parts of the head. The teeth of the upper jaw are vestigial.

by the long arms of the manubrium and travels in their folds to the mouth. These and other modes of feeding which gather only small objects for food are known as "microphagy": in them little

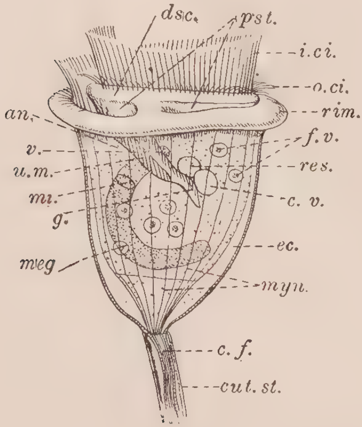


FIG. 37.—A *Vorticella*, showing the apparatus by which food is gathered and swallowed, and the food in vacuoles circulating in the body.

an., Position of temporary anus; *c.f.*, contractile filament; *c.v.*, contractile vacuole; *cut.st.*, cuticle of the stalk; *dsc.*, disc; *ec.*, ectoplasm; *f.v.*, food vacuoles; *g.*, gullet; *i.ci.*, inner row of cilia; *meg.*, meganucleus; *mi.*, micronucleus; *myn.*, myonemes; *o.ci.*, outer row of cilia; *pst.*, peristome; *res.*, reservoir of contractile vacuole; *rim*; *u.m.*, undulating membrane; *v.*, vestibule

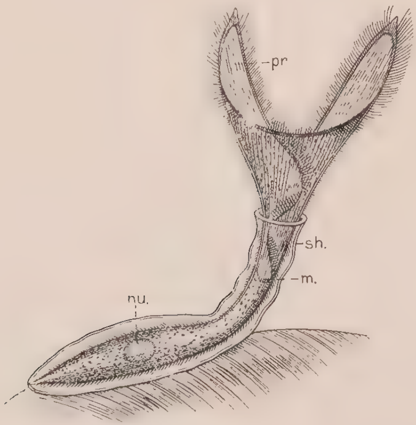


FIG. 38.—*Folliculina*, showing the food-gathering cilia raised upon lobes of the body, and the house by which the animal is protected.

m., Mouth; *nu.*, nucleus; *pr.*, lobes bearing strong cilia; *sh.*, house.

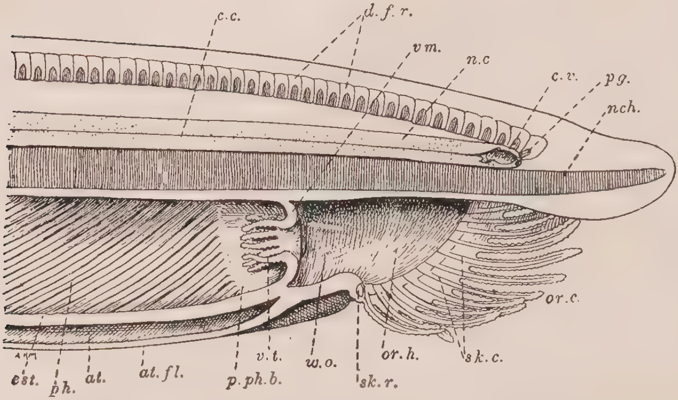


FIG. 39.—The forepart of the body of the Lancelet (*Amphioxus*), cut in half longitudinally, to show the feeding apparatus. The cirri collect the food in the first instance, the wheel organ helps to pass it into the mouth, where the velar tentacles keep out coarse particles, and the endostyle secretes mucus which, passing upwards over the perforated walls of the pharynx, entangles the fine food particles and carries them backwards to the œsophagus (not shown), letting the water be driven by cilia out into the atrium.

at., Atrium; *at.fl.*, atrial floor; *c.c.*, central canal of nerve cord; *c.v.*, cerebral vesicle; *d.f.r.*, dorsal fin rays; *est.*, endostyle; *n.c.*, nerve cord; *nch.*, notochord; *or.c.*, oral cirri; *or.h.*, oral hood; *p.ph.b.*, peripharyngeal band; *pg.*, anterior pigment spot; *ph.*, pharynx; *sk.c.*, skeleton of cirri; *sk.r.*, skeleton ring in oral hood; *v.t.*, velar tentacles; *vm.*, velum; *w.o.*, part of wheel organ.

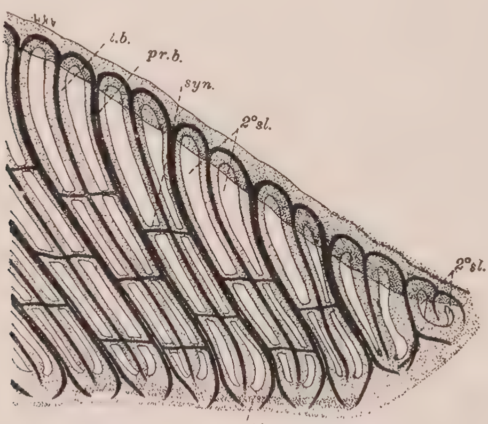


FIG. 40.—The hinder end of one side of the pharynx of *Amphioxus*, showing the structure of the clefts in the wall.

est., Endostyle; *pr.b.*, primary bar; *syn.*, synapticulæ; *t.b.*, tongue bar; 2°*sl.*, the two secondary gill slits which arise from a primary slit. The skeleton is shown in black.

discrimination is exercised, but, so long as the apparatus is working particles of all kinds, animal, vegetable, and mineral, are swallowed together, provided that they be of a size with which it can deal. Microphagy is a very widespread habit, and testifies to the enormous mass of food which the water contains in suspension, as minute living organisms and dead particles of various kinds. (*e*) Again, there may come to the aid of the mouth appendages of various kinds, such as the tentacles of zoophytes and holothurians, the tube-feet of echinoderms, the arms of cuttlefishes, and the paired limbs of arthropoda and certain vertebrata—parrots, birds of prey, cats, various rodents, monkeys, and Man. Appendages such as these may be sticky, as in some holothurians (Fig. 15); or fringed with bristles and used to sweep the food to the mouth, as in barnacles (Fig. 231); or

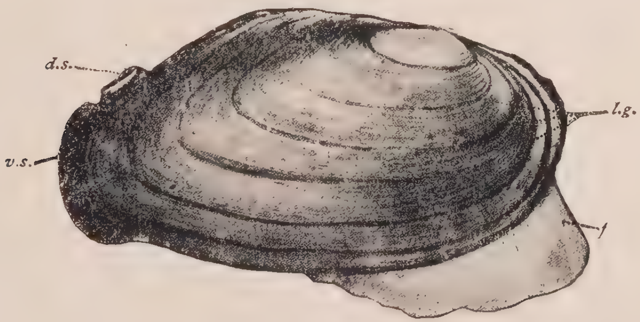


FIG. 41.—A swan mussel (*Anodonta cygnea*) from the right hand side, showing the siphons through which the water flows in (*v.s.*) and out (*d.s.*). *f.*, foot; *l.g.*, lines of growth.

be provided with special means of prehension, such as nematocysts, suckers, claws, pincers, or opposable fingers: they may be used singly, or those of opposite sides of the body may combine in action. Claws are the hard, slender, usually pointed ends of limbs, used for holding, or holding on, or tearing. They are found on such different structures as the legs of insects and crustaceans, the hands and feet of vertebrates, and the grapplers or "cirri" of the Feather Star (*Antedon*), which, of course, does not use them for taking food. When a claw folds back like the blade of a pen-knife against the preceding joint of its limb, as in the first limb of a spider or the "claw" of a shrimp, it is known as a *subchela*. When it bites against a process of the preceding joint, as in the "claws" of crabs and scorpions, it forms a pincer or *chela*. In arthropoda some of the limbs are intimately associated with the

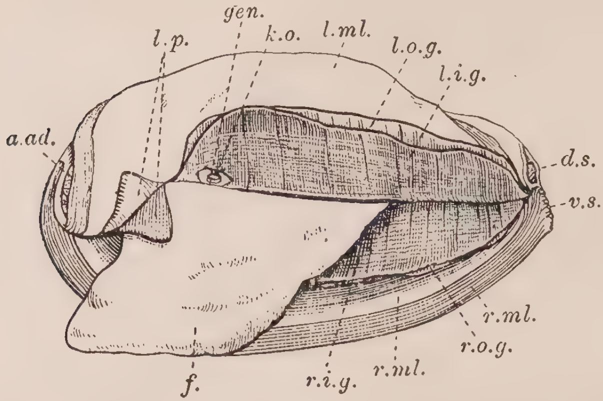


FIG. 42.—A swan mussel removed from its shell and lying on its right side with the left mantle lobe and left gills turned back. A portion of the inner lamella of the left inner gill has been cut away to show the openings of the kidney and gonad.

a.ad., Anterior adductor muscle; *d.s.*, dorsal siphon; *f.*, foot; *gen.*, opening of the duct of the gonad; *k.o.*, opening of the kidney; *l.i.g.*, left inner gill; *l.m.l.*, left mantle lobe; *l.o.g.*, left outer gill; *l.p.*, labial palps; *r.i.g.*, right inner gill; *r m.l*, right mantle lobe; *r.m.l'.*, thickened edge of the same; *r.o.g.*, right outer gill; *v.s.*, ventral siphon.

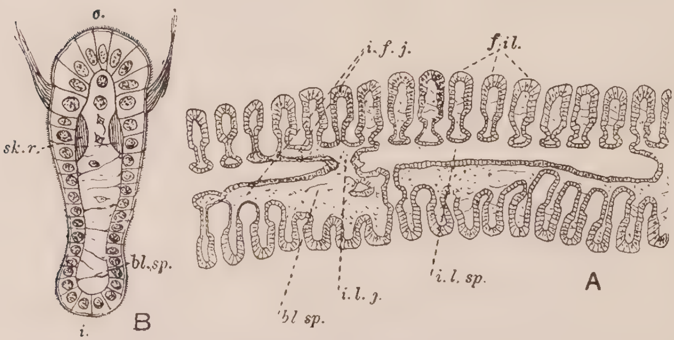


FIG. 43.—*A.*, a horizontal section through a gill of the swan mussel, under low magnification, showing the openings between the filaments (*fil.*) that compose the gill, and the space *i.l.sp.*, within the gill. The water is caused by cilia on the sides of the filaments to flow through the openings into the space and thence out by the dorsal siphon. The food particles are thus strained off and driven by other cilia on the outside of the gills to the labial palps, which feed the mouth. *B.*, a single filament, more highly magnified, showing cilia.

bl.sp., Blood spaces; *fil.*, filaments; *i.*, edge of filament towards interlamellar space; *i.f.j.*, interfilamentar junction; *i.l.j.*, interlamellar junction; *i.l.sp.*, interlamellar space; *o.*, outer edge of filament; *sk.r.*, sections of the chitinous skeletal rods which support each filament.

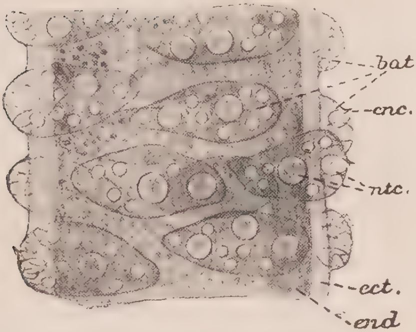


FIG. 44.—Part of a tentacle of *Hydra* magnified.

bat., Batteries of nematocysts; *cnc.*, cnidocil; *ect.*, ectoderm; *end.*, endoderm; *ntc.*, nematocysts.

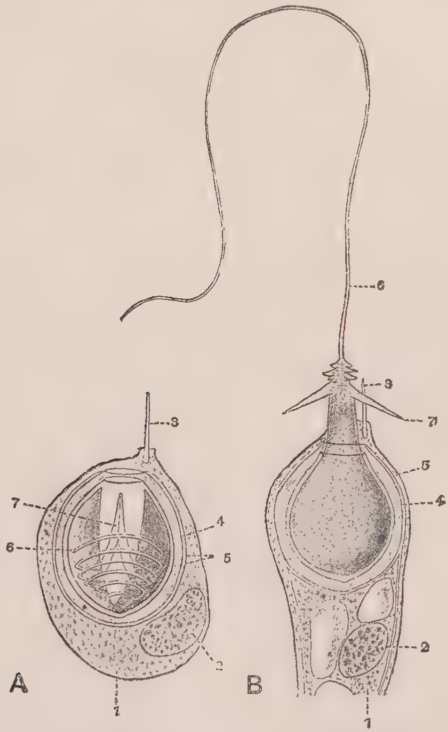


FIG. 45.—Nematocysts of the Brown Hydra in their cnidoblasts.—From Schneider.

A., Unexploded; *B.*, exploded.
1, Cnidoblast; 2, nucleus of cnidoblast; 3, cnidocil; 4, contractile sheath; 5, wall of nematocyst; 6, thread; 7, barbs.

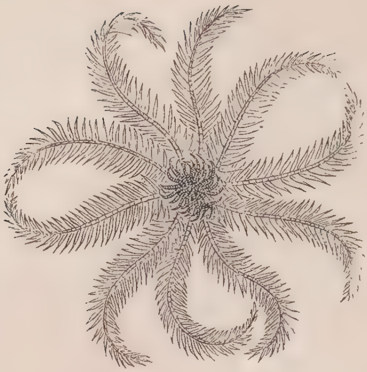


FIG. 46.—The Feather Star (*Antedon*), from the aboral side, showing the arms by which the animal gathers food (through ciliary action), and also swims, and the cirri by which it anchors.—From Thomson.

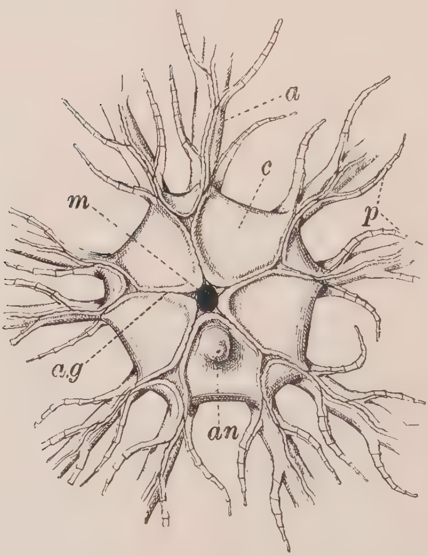


FIG. 47.—An oral view of the disc and bases of the arms of the Rosy Feather Star (*Antedon rosacea*).—From MacBride.

a., Arm ; *a.g.*, ambulacral groove along which food passes to the mouth ; *an.*, anus ; *c.*, calyx ; *m.*, mouth ; *p.*, pinnules.

mouth and serve as jaws, or form a sucking tube, in which there may be piercing stylets, as in mosquitoes. (*f*) In a few cases, animals

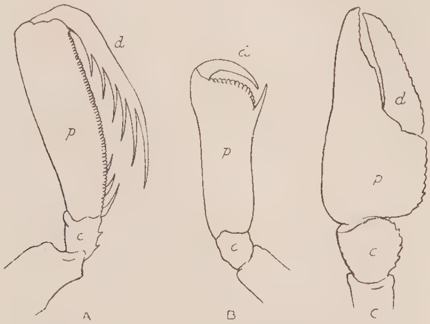


Fig. 48.—Examples of three types of arthropod grasping organs.

A., The great subchela of *Squilla*; *B.*, the subchela of the shrimp; *C.*, the great chela of the crayfish. Not drawn to scale.
c., carpopodite; *d.*, dactylopodite; *p.*, propodite.

form snares in which they entrap their food; and these may be in addition to jaws, as in spiders, the web-spinning water larvæ of

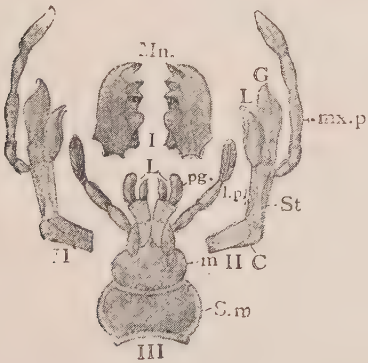


Fig. 49.—The mouth appendage of a cockroach.—After Dufour.

I., *Mn.*, mandibles; II., maxillæ; *C.*, cardo; *St.*, stipes; *L.*, lacinia; *G.*, galea; *mx.p.*, maxillary palp; III., labium; *S.m.*, submentum; *m.*, mentum; *L.*, laciniæ; *pg.*, paraglossa; *l.p.*, labial palp.

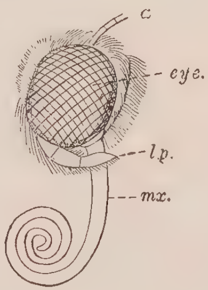


Fig. 50.—A side view of the head of a butterfly, showing the long suctorial proboscis formed by the maxillæ.

a., Antenna; *eye*; *l.p.*, palp of the labrum; *mx.*, maxilla.

hydropsychid caddis-flies (Fig. 282), and the pitfall-digging larva of the Ant-lion, which are, of course, carnivorous; or in substitution for them, as in the appendicularian tunicates, which secrete a "house"

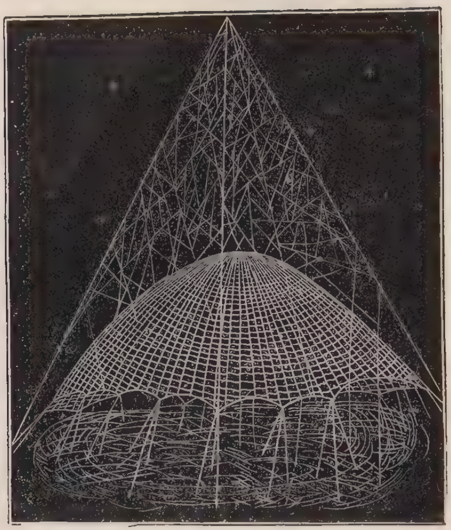


FIG. 51.—The snare of the spider *Epeira basilica.* —From Warburton, after McCook.

FIG. 52.—The Ant-lion, its larva, and the pit made by the latter, into which the prey slide, while the larva throws sand at them to hasten their descent.

with a straining apparatus (Fig. 54), and are microphagous. *Peripatus* entangles its prey in sticky threads which it throws out from its slime papillæ (Fig. 99). (*g*) Finally, the mouth is sometimes protrusible upon an "introvert," as in whelks, sipunculid worms, etc. A similar but more extreme case is seen in the Starfish, which extrudes the whole of its stomach to enclose the body of its prey.

As is well known, the diet of animals varies greatly. It may, as in insects with one food plant, be restricted to a single organ, such as the leaf or seed, or to the bodies of a single species of organism, or may comprise a few kinds of food or many. In the last case the animal may be herbivorous, or carnivorous, or have a mixed diet; though not even so-called

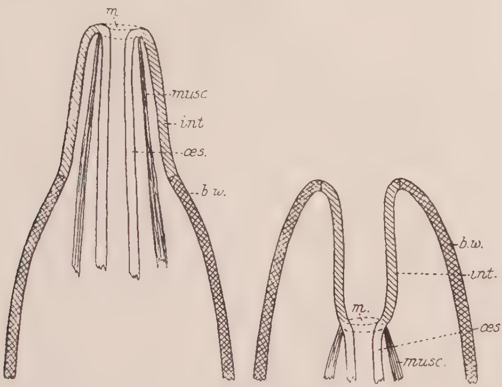


Fig. 53.—A diagram of an introvert.

b.w., Body wall of the animal; *int.*, introvert; *m.*, actual mouth; *musc.*, muscle by which introvert is withdrawn; *œs.*, œsophagus.

omnivorous animals, such as Man, or the Pig, or the Crayfish, are able to use for food the bodies of all other organisms. Sometimes, as in microphagous animals, in those which, like earthworms and many marine animals, swallow soil, sand, or ooze, and extract from it the organic nourishment which it contains, and to some extent in whalebone whales, feeding is necessarily indiscriminate; in other cases a choice is possible. Diet is governed by various factors. It depends upon the facilities which the organization of the animal affords for obtaining food—its size, seizing organs, mouth-armature, etc.—upon its digestive ferments or those of other organisms which live in its intestine and assist it in dissolving its food (p. 62), and upon instincts which lead it to feed upon certain creatures and not upon others. These instincts correspond to

certain necessities of its physiology. An animal needs in its food (1) water; (2) certain inorganic salts (both of which it may obtain from its inorganic surroundings, but sometimes takes only in the bodies of organisms); (3) organic substances containing enough potential energy to replace that lost as work and heat, these being largely carbohydrates (starches and sugars) and fats, but partly also proteins; (4) protein material to replace that which is lost in the wear and tear of the tissues. This need not consist of

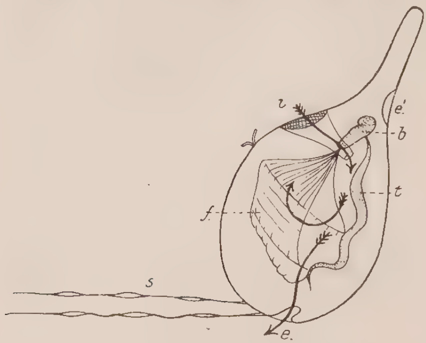


FIG. 54.—*Oikopleura albicans*, an appendicularian tunicate, in its "house," seen from the side. Diagrammatic.—Partly after Lohmann.

The animal lies with its mouth applied to the narrow end of the fishing apparatus, and by the movement of its tail causes water to enter through two funnels on the back of the house. These funnels are provided with gratings by which coarse particles are strained out. A current flows through the fishing apparatus, which entangles minute particles that are then sucked out by the animal for food. Another current leaves by an opening at the broad end of the house, driving the house in the opposite direction. The animal can escape by an opening at the base of the beak of the house. It does not return, but secretes a new house.

b., The body of the animal; *e.*, hinder opening; *e'.*, opening of escape; *f.*, fishing apparatus; *l'.*, one of the funnels; *s.*, streamers; *t.*, tail.

proteins identical with those of the body, since the animal manufactures those which it requires by decomposing the proteins of its food, during digestion, into the amino-acids of which they are composed and recombining these so as to meet its own protein needs. The food must, however, supply the right amino-acids in sufficient quantities for the manufacture of the proteins of the body. It has been shown, for instance, that mice are unable to support life upon a diet in which the only protein present is zein, the protein of maize, which does not contain the important constituent tryptophane. (5) Animals are also under the necessity of obtaining in their

food the mysterious substances known as "vitamins," which, originally manufactured by plants, are transmitted to herbivorous animals and by them to others, and, though in very small quantities, are essential to life. The nature and mode of action of these substances are unknown, but they may be recognized by their effects. Thus, of the three which are at present known, two (vitamins A and B), soluble respectively in fats and in water, must be present for normal growth to take place in the animals in which they have been investigated. When young rats are fed upon an artificial liquid containing the protein, fat, and sugar of milk in their usual proportions, they fail to grow; but the addition to their diet of a very small quantity of fresh milk (which contains the vitamins) causes them to grow in a normal manner. The absence of the second of these vitamins from the diet of mammals and birds is followed in adults by inflammation of the nerves (polyneuritis). In man the disease known as beri-beri, characterized by nervous symptoms and wasting, is thus caused in individuals whose diet consists almost solely of polished rice, that is, of rice from which the husk, which contains the vitamin, has been removed. The addition to the diet of rice husks, yeast, meat-juice, or various other natural substances supplies the vitamin and cures the disease. A third vitamin (C), also water-soluble, is obtained by animals from fresh vegetables and other fresh foods. Its absence causes scurvy. While, however, all animals have these general requirements in diet, their needs vary greatly in detail. The

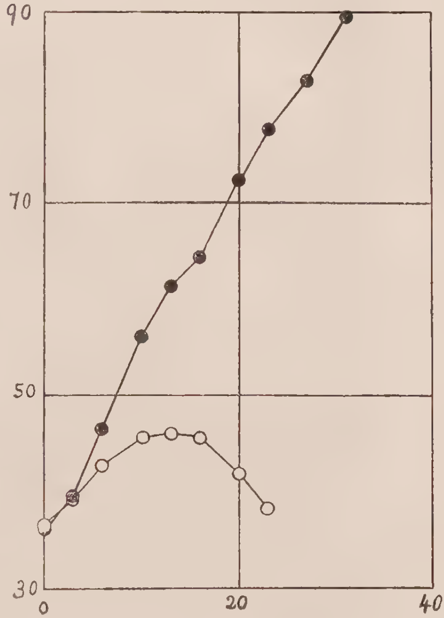


FIG. 55.—Curves showing the effect of vitamins on growth.—From Hopkins.

Lower curve (white circles), rats fed on artificial milk alone; upper curve (black circles), rats fed on artificial milk + 2 c.c. of cow's milk daily.

chemical composition of the bodies of animals varies greatly, and it is safe to say that no two of them contain exactly the same substances in the same proportions. This is particularly important in the matter of proteins. Further, each constituent is expended at

FIG. 56.—The Goat Moth (*Cossus ligniperda*) with its larva and pupa —After Duncan.

a different rate in different animals. The loss of water and salts, the breaking down of organic substances to provide energy, the wear and tear of the proteins of the tissues, proceed differently in different cases, according as the animals live in damp or dry surroundings, are aerobic or anaerobic (p. 197), active or sluggish, and

so forth. Thus the ideal food of every animal would differ more or less from that of every other. Actually, it is probable that the diet of no animal is ideal, but that each, while it eats the best food that it can get, is obliged, in order to obtain enough of some substances, to

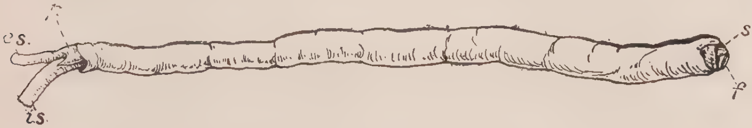


Fig. 57.—A Shipworm (*Teredo navalis*).—From Calman.
e.s., Exhalant siphon; *f.*, foot; *i.s.*, inhalant siphon; *p.*, one of the "pallets"; *s.*, one valve of the shell.

swallow more of others than it needs and yet others that it has no use for. A remarkable diet is that of certain animals—chiefly wood-borers (p. 90), such as various insects and the Shipworm (*Teredo*)—whose food consists principally or wholly of wood. To digest the

Fig. 58.—Part of a pile of fir-wood from Torquay Harbour attacked by *Teredo norvegica*.—From Calman.
The surface of the wood has been eaten away by the isopod crustaceans *Limnoria* and *Chelura*, exposing the burrows of the *Teredo*, the shelly lining of which can be seen in many places. Much reduced.

peculiar form of cellulose of which this is mainly composed they appear sometimes, as in the Shipworm, to secrete a special ferment, but more often to call to their aid certain bacteria or moulds which inhabit their intestines (p. 62).

The individual animal is, of course, greatly affected by the amount and quality of its food. Not only the general health and capacity for exertion, but the rate of growth and reproduction, especially of sessile animals and parasites, the development of bodily form, the production of sexual individuals, encystment, and other processes are directly influenced by these circumstances.

The relation of the size of an animal to that of the organisms which serve it for food varies greatly. A main part of the food of the sea is provided by minute floating plants which feed the smallest animals, and it is probably true to say, speaking very broadly, that the food supply accumulated by these plants, as it is dissipated by animals, passes through larger and larger bodies, until it comes finally to be disintegrated by the scavengers, which very generally are smaller than the bodies on which they feed. On land, however, it is often otherwise. There, a herbivorous animal is perhaps usually smaller than the plants which serve it for food; and though, for obvious reasons, it less often happens that a carnivorous animal is smaller than its prey, there are plenty of instances, from wolves to mosquitoes, in which it is so. When a small attacker becomes resident, permanently or for a considerable time, upon or in the organism from which it derives its food, it is known as a parasite, though, as we shall see, food is not the only benefit that a parasite may derive from its host.

FIG. 59.—The outer surface of the right valve of the shell of a shipworm. — From Calman.

The notched edge to the right is the front edge, and the two sets of fine ridges parallel to the sides of the notch are used to rasp the wood.

With the relation between an animal and other organisms are connected many of its most conspicuous features. Some of these, such as organs which serve solely to obtain food, weapons and defensive apparatus, all the colours, ornaments, light and sound-producing organs, habits, etc., which render it conspicuous or inconspicuous, or otherwise affect communication between it and with other animals, and the organs used only in the intercourse of the sexes and in the care of the young, are concerned in the traffic between organisms alone. Others, such as the organs of sense, the nervous system, and to some extent the organs of locomotion, attain a high development in proportion to the part they play in the relations

between their possessor and organisms in its surroundings. An animal, for instance, which lives an active and conspicuous existence is by its sense organs readily aware of the presence of enemy or prey or of its mate, and is enabled by its nervous system instantly to take the necessary action. In particular, to such animals organs of sight and those by which vibrations like those of sound are perceived are of importance. To a sedentary animal organs of distant perception are of less necessity, but the tactile and chemical senses are still important. In an internal parasite, organs of perception and locomotion are usually reduced to a minimum. More

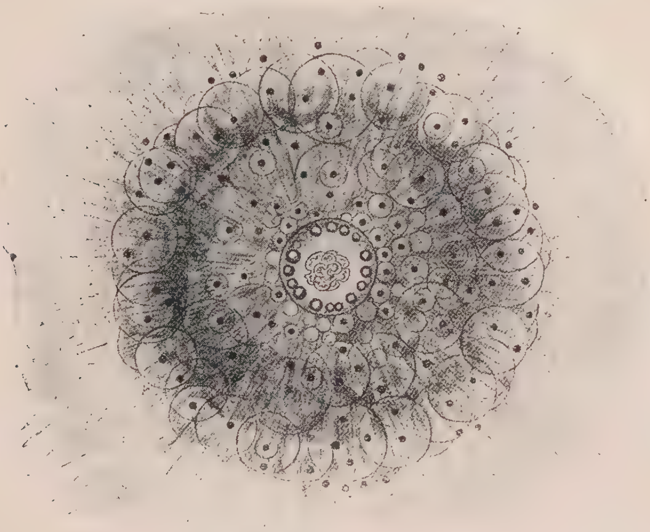


FIG. 60.—The radiolarian *Thalassicolla*, showing the bubbles and yellow cells in the extracapsular protoplasm, the capsule, the nucleus in the intracapsular protoplasm, and the pseudopodia.—From Hertwig.

indirectly, indeed, the whole body of an animal betrays a relation to other living beings. We have already seen how the fundamental differences which distinguish animals from plants—their bodily forms, their mobility, the nature of their tissues, and so forth—are connected in the long run with their dependence upon organisms for nutriment. Closely though their respiratory, locomotory, skeletal, and other systems are adapted to the physical conditions in which they live, it is their relation to their organized environment that is the dominating characteristic of their organization.

We may enumerate the several kinds of relation in which an animal may stand with other organisms under two primary head-

ings, containing respectively relations with plants and those with other animals. With the nature of the general relations between

FIG. 61.—*Cryptomonas schaudinni,* a plant-like flagellate which is symbiotic with the foraminiferan *Peneroplis.*—From Doflein.
A., Free swimming; *B.*, within its host; *Chr.*, chromatophore; *N.*, nucleus; *St.*, starch.

the animal and plant kingdoms we have already dealt, and we have seen that they are relations of reciprocal nutrition, and that in fact the life of animals would be impossible without that of plants. Very often, however, special and more intimate relations are established between individual animals and plants.

FIG. 62. — *Convoluta roscoffensis.*
a, Algæ; *e*, eyes; *ot.*, otocyst.

1. In most of these one partner, at least, directly provides nutriment for the other. (*a*) In one series a specializing of the general relation takes place, so that *reciprocity of nutrition* is maintained between individual animals and plants, by the fact that plants live within the bodies of animals. This is known as *Symbiosis.*[1] (i) In one kind of it the plant is a minute, green, yellow, or brown alga belonging to the Phytomastigina (Plant-like Flagellates), and lives in the animal in great numbers in its resting (non-flagellate) phase. The animal may be a protozoon of the Radiolaria, Foraminifera, Ciliata, etc., a sponge, a cœlenterate, as the Green Hydra, or more rarely a member of one of the higher subkingdoms — a flatworm, as *Convoluta*, a polyzoon, a mollusc, or a sea-urchin.

[1] This word has been very variously used. It is sometimes applied to plant-animal relations of the type described above, sometimes to all relations between organisms in which the benefits are mutual, and sometimes to all intimate associations between organisms, including parasitism.

Each host always shelters the same species of alga, which, if it be green, is known as a *Zoochlorella,* if yellow as a *Zooxanthella.* Some of the algæ have been found leading a free life; others have not. They generally infect new individuals of the host in their free-swimming flagellate phase, and often, as in *Convoluta,* gain entry by being swallowed but not digested by the animal, which for its own purposes tolerates them: sometimes, however, they are passed on from one generation to the next,

FIG. 63.—Part of the body of a green *Hydra,* showing green cells in the endoderm, a testis, and a ripe ovum hanging free. In the ovum may be seen green cells which have passed into it from its parent.

as in *Hydra,* where they are found in the ovum. They embed themselves in the protoplasm of their host and there multiply by division. Whatever their colour, they contain chlorophyll, and nourish themselves in the translucent tissues of the animal with the aid of sunlight after the manner of plants. Some of them form for themselves a delicate wall of cellulose; others, like those which infest *Convoluta,* do not. To them the benefit of the close partnership is the ease with which they obtain the carbon dioxide and nitrogenous waste products of their host. The animal partner benefits

by the supply of oxygen set free in its tissues, and by the removal of its waste products ; but most by nourishment which it derives from the plant, sometimes by the diffusion of carbohydrates, sometimes by the extrusion of fat, and eventually by killing and digesting its lodger. This is done in various circumstances, when the light is feeble, or other food is lacking, or the algæ are beginning to degenerate. The closeness of the association varies. Sometimes the animal partner always contains symbiotes, sometimes it can live without them. Thus *Convoluta roscoffensis* at an early stage ceases to feed, and becomes dependent for nourishment upon the green algæ which it always contains, and the green Hydra is never found without its symbiotes ; but *Noctiluca* is colourless

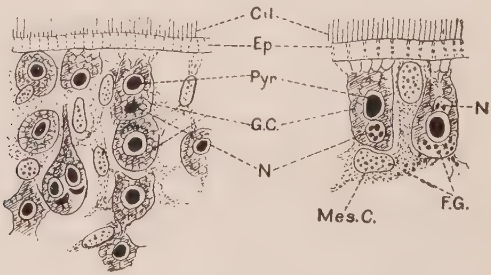


Fig. 64.—A section of the superficial tissues of *Convoluta roscoffensis.*—From Keeble.

Cil., Cilia ; *Ep.*, epidermis ; *F.G.*, fat globules, formed in the plant and passed into the tissues of the animal ; *G.C.*, the green cells, in rows, of which the younger members are degenerate, without nuclei ; *Mes. C.*, attendant cells of the mesenchyme of the animal, which eventually devour the green cells ; *N.*, nuclei of green cells ; *Pyr.*, pyrenoids of the green cells.

in the North Atlantic and green in the Indian Ocean. Whether there be any species of alga which lives only as a symbiote is unknown. Often the animal ceases to feed when the infection is well established, and has light-seeking habits suitable to its mode of nutrition. (ii) In another kind of symbiosis, the plant is a bacterium, and perhaps sometimes a fungus, and lives in the stomach or intestine of its host, for which, and not for other organisms in general, it performs its function of dissolving and rendering assimilable the remains of the dead bodies of plants or animals—in this case those taken as food by its partner. It is thus that ruminant animals, for instance, digest the huge quantities of cellulose that their food contains, absorbing probably the sugars and perhaps also fatty acids produced from it by the bacteria in their intestines, and many wood-eating creatures are nourished by the hard fibres

which form a great part of their food. The bacteria benefit by the fact that the animal prepares plant remains for their use by disintegrating them, mixing them with water and keeping them at a suitable temperature. Here we may also place the remarkable habit of certain ants (*Atta*, etc.) which cultivate fungi for food, growing them upon fragments of leaves which they cut from plants and store in their nests.

In the remainder of the special relations of nutrition between members of the two kingdoms of living beings, the provision of nutriment is one-sided, either the animal or the plant alone benefiting in this respect.

(*b*) When *the animal is nourished*, it may or may not confer a benefit of some other kind in return. (i) In the simplest case, *the animal feeds exclusively upon a particular plant.* On this, which is

Fig. 65.—The Turnip-leaf Plant-louse (*Aphis rapæ*).—After Curtis.

2 and 4, winged and wingless parthenogenetic females; 1 and 3, natural size of the same.

familiar in the larvæ of many insects, we need not dwell. (ii) Many animals—protozoa, nematode worms, copepod crustaceans, mites, etc., and especially insects of all orders—are *parasitic upon plants.* These animals may reside internally or externally upon their hosts. They present, in various degrees, the general features of parasites, such as degeneracy, in the parasitic stage, of organs of locomotion and sense, great powers of reproduction, alternation of generations, often a sucking apparatus, and so forth, which we shall discuss later. Here, however, something must be said about a peculiar feature of parasitism upon plants, namely, the frequent production of galls. These are abnormal growths, either of tissues or of whole organs (leaves, flowers, etc.) of the plant, produced by poisons applied to it either by the female of the parasite in egg-laying, or by the larva, or perhaps sometimes by the eggs. They are formed by certain members of each of the orders of animals which are parasitic upon plants, but especially of the Plant Lice or Aphidæ (*Hemiptera*), Gall

Flies or Cynipidæ (*Hymenoptera*), and Gall Midge Flies or Cecidomyidæ (*Diptera*). The "oak-apple," for instance, is formed by the cynipid *Andricus terminalis*, certain common galls on the leaf-stalks of poplars by a cecidomyid. Galls are found on plants of all classes, but are less common on cryptogams than on phanerogams. They may be situated on any part of the plant, including the roots,

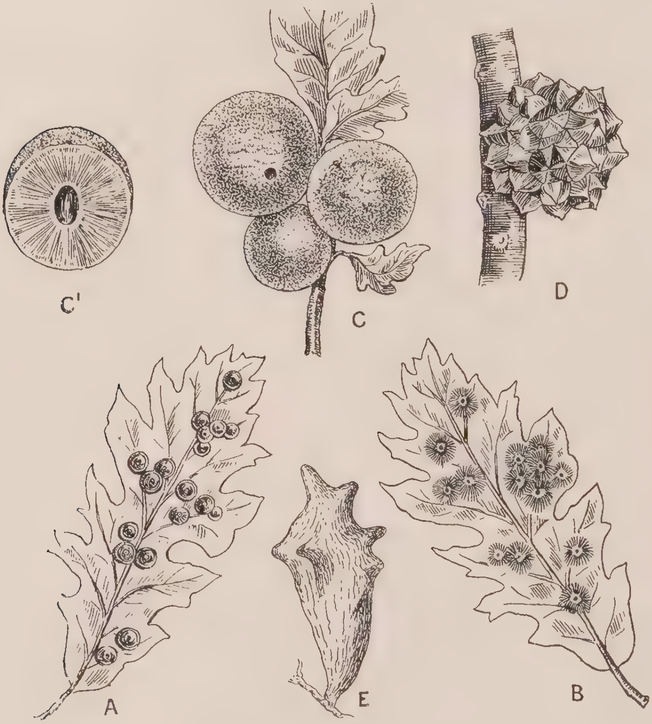


FIG. 66.—Galls.—After various authors.

A., *B.*, Galls on oak leaves formed by two species of the gall-fly *Neuroterus* ; *C*, *C'*., oak apples ; *D.*, a gall produced from a foliage bud by a species of *Cynips* ; *E.*, Chinese gall, produced on a Sumach by an *Aphis*.

and vary enormously in size, shape, colour, and internal structure according to the species of animal which produces them. They shelter the gall-forming parasite during its development, but also often a number of other animals, mostly insect larvæ and frequently related to the gall-formers, some of which ("inquilines") are harmless, and nourish themselves on the tissues of the galls which they cannot produce, or merely seek shelter, while others attack the gall-parasite itself or the inquilines, usually as parasites upon them.

The number of these alien inhabitants of galls is surprisingly large. In the galls formed by a single species of gall-fly (*Biorrhiza aptera*) there have been found as many as eleven inquiline species and seventy-nine of enemies. (iii) In another series of cases, plants

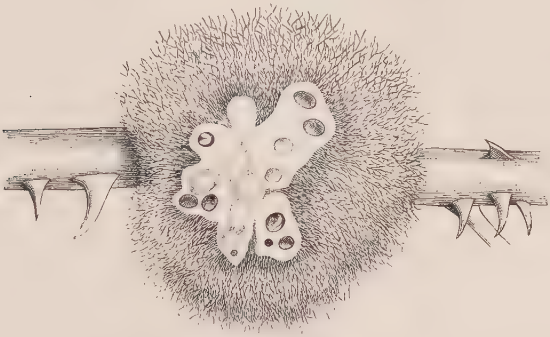


FIG. 67.—A bedeguar gall from a rose tree, cut across to show the chambers of the larvæ. In some of the chambers larvæ are seen.—From Sharp.

may be said to *hire* animals, by the provision of some special kind of food, to perform special services, namely, fertilization by the transference of their pollen, the distribution of seeds, and defence against enemies. Space will not permit that we should enter in detail into

FIG. 68.—The gall-fly *Rhodites rosæ* by which the bedeguar is formed.—From Sharp.

this subject, and it is the less necessary that we should do so since a whole literature is devoted to it. It is enough that we should here recall that the pollen is situated in the complex plant-organs known as flowers, which also contain the carpels; that the

attractive food is nectar secreted by some part of the flower, sweet-sap, or the pollen itself; that its presence is advertised by the colour and smell of the flowers; and that the structure of the flower is

FIG. 69.—Larvæ that inhabit bedeguar galls.—From Sharp.

1, *Rhodetes rosæ*, in cell; 2 and 3, inquilines; 4, larva of a parasitic hymenopteron.

such as to ensure, often by the most complicated devices, that the animal in obtaining its food removes some of the pollen upon its body and deposits it upon the female organs of the same plant or

FIG. 70.—The fertilizing of the flowers of *Marcgravia nepenthoides* by a humming-bird which is feeding on the nectar in the pitchers which the plant bears.—From Wallace.

some other of the same species. The animals which fertilize plants are usually insects, but cases are known in which birds, snails, and even mammals perform this service. Very often the flower, from

its shape or time of opening, can be fertilized only by a few species of insect, or even only by one, and then the adjustment between the two is marvellously close. Sometimes the visits of the insect are made for the purpose of laying its eggs rather than, or as well as, to obtain nectar. Then the larvæ develop in the flower and feed on the ovules—but do not destroy them all—and the food-bribe offered by the plant is nourishment to the young rather than to the adult. This relation exists in our own country between various moths of the Noctuæ and caryophyllacean flowers, such as the Ragged Robin and Bladder Campion; but it is more elaborate in

FIG. 71.—The fertilization of the Yucca.

On the right the Yucca Moth (*Pronuba yuccasella*) approaching a flower. On the left a flower cut open, showing the stamens and stigma, with the moth placing the pollen in the hollow at the end of the stigma.

certain instances in warmer countries, as in the case of the Yucca Moth (*Pronuba yuccasella*), which collects a ball of pollen from one flower and with it fertilizes another in which it lays its eggs; and in that of the hymenopterous insect *Blastophaga* which fertilizes figs, and is profoundly modified in its life-history in correspondence with this habit. A fig is a hollow inflorescence, lined with small male and female flowers. The eggs of the *Blastophaga* are laid in female flowers, of which there are sometimes two kinds, in one of which the insect can reach the ovary while in the other she cannot, so that it is safe from her attacks. The larvæ form minute galls from the ovaries of the flowers, and from these there emerge males,

which are wingless, and females, which are winged. After impregnation the females leave the fig, brushing off pollen from the male flowers near the entrance as they do so, and enter a young inflorescence, where they lay their eggs, fertilizing the flowers as they do so with pollen brought from the inflorescence in which they were born. To hire the assistance of animals in distributing their seeds, plants provide the fleshy parts of fruits; and the seeds either pass, in their hard coats, undigested through the alimentary canal of the animal and are distributed in its droppings, or are thrown away by it after they have been carried to a distance. Lastly, there are cases in which the services of ants are retained by plants,

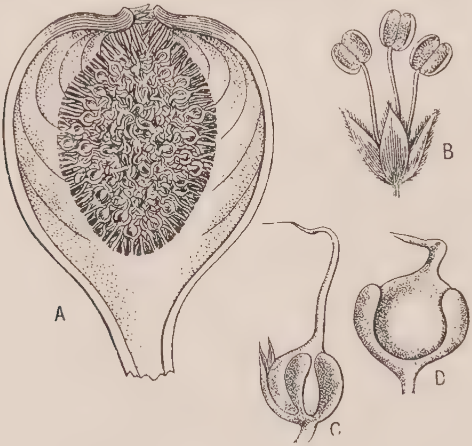


FIG. 72.—The structure of a fig.

A., An inflorescence (*syconium*) of *Ficus carica* cut open; *B.*, a male flower magnified; *C*, a normal female flower; *D.*, a gall, formed in a gall-flower.

not for purposes of reproduction or distribution, but for defence. There is, for instance, a species of acacia (*A. sphærocephala*) upon which grow little pear-shaped masses of food for the ants, and hollow thorns in which they shelter. In return the ants defend the plant from the attacks of other insects. It is suspected that in other cases mites are retained by trees to defend them from bacteria and fungi.

(*c*) In yet another series of special relations between plants and animals, the plant instead of obtaining disintegration products of animal bodies from the soil and air, *captures animals* and destroys them so as to obtain immediately and in a concentrated form the materials of their bodies, much as animals themselves are nourished.

Sometimes the animals are merely retained by the plant till they decay, and their decomposition products are then absorbed. Other

FIG. 73.—An underwater branch of the Bladderwort, showing the divided leaves and the bladders which they bear.—From Darwin.

carnivorous plants secrete digestive juices and in quite animal fashion avail themselves of the nourishment in their prey. A

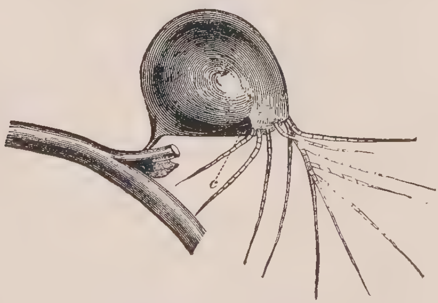


FIG. 74.—A bladder of the Bladderwort, much enlarged.—From Darwin.

c., Position of the opening.

British example of the first of these methods is afforded by the Bladderworts (species of *Utricularia*). These water plants feed upon small aquatic organisms, which they catch in little bladder-

like traps formed by modification of parts of the feathery leaves. Each trap is not unlike a large water-flea in shape, and has two branching bristles at the free end. Here is placed the small opening into the bladder, guarded by a little transparent flap serving as a door, which opens inwards with the greatest ease, but prevents exit. Why little creatures should be attracted to these traps is not clear, but minute crustaceans, etc., are for some reason apt to pry into

FIG. 75.—The Pitcher Plant (*Nepenthes*).—From Strasburger.

holes and corners, and possibly they make use of the two branching bristles as a place of refuge from their enemies. As these bristles act as guides to the mouth of the trap the result is often fatal. Slimy hairs which grow in this dangerous neighbourhood possibly provide some attraction, while the little transparent door may look like a spot of light, and act as a lure. In any case victims are numerous, and their decomposed remains are absorbed by certain branched hairs which line the trap. The second method, as prac-

tised by the Pitcher Plant (*Nepenthes*) by means of the curious lidded pitchers into which its leaves are hollowed, is described by Davis as follows: "*Nepenthes destillatoria* [is] a typical species of the group of pitcher plants, which ranges from Madagascar through

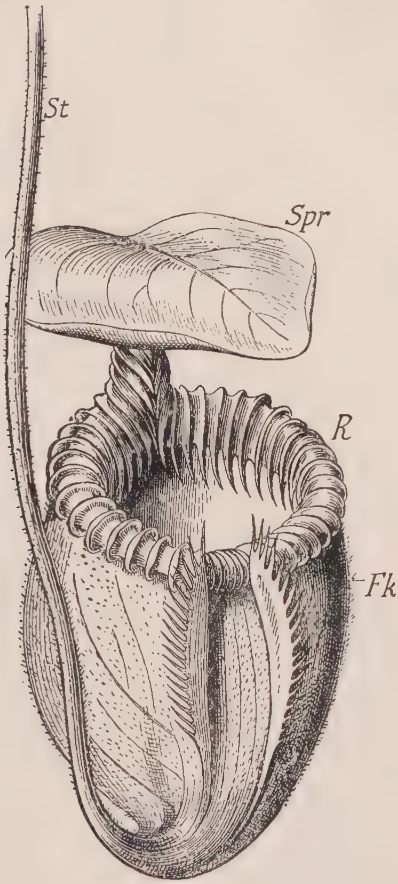


FIG. 76.—A pitcher of *Nepenthes villosa.*—From Weismann.

Fk., Pitcher; *R.*, margin with incurved spines which prevent insects from escaping; *Spr.*, apex of leaf; *St.*, stalk.

south and south-east Asia to the East Indies, Philippines, and tropical Australia. They live in damp forest-regions, at the side of pools, in the shallow water of which their seeds germinate. The leaves are modified in a remarkable manner for the purpose of catching and digesting flying insects. The attached end of the

leaf-stalk is broadened into a green expansion, followed by a tendril-like section, while the end of the stalk swells into a pitcher, which is overhung by a lid representing the blade of the leaf. Insects are attracted by the bright colours of the pitchers, and the nectar which is abundantly secreted around their openings and on the under side of their lids. But the inner side of the pitcher is as slippery as glass, and any insect that steps upon it quickly slides down into the contained fluid, which partly consists of a powerful

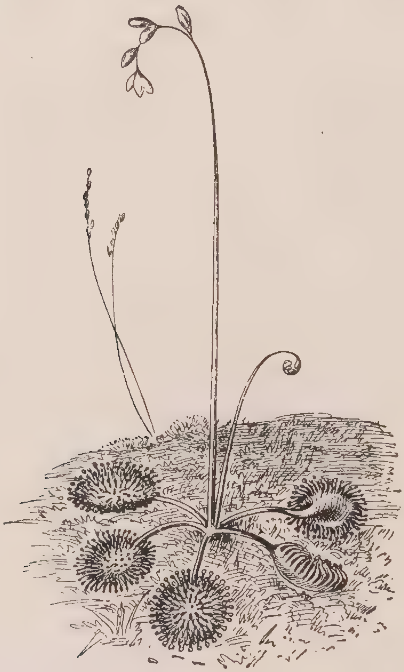
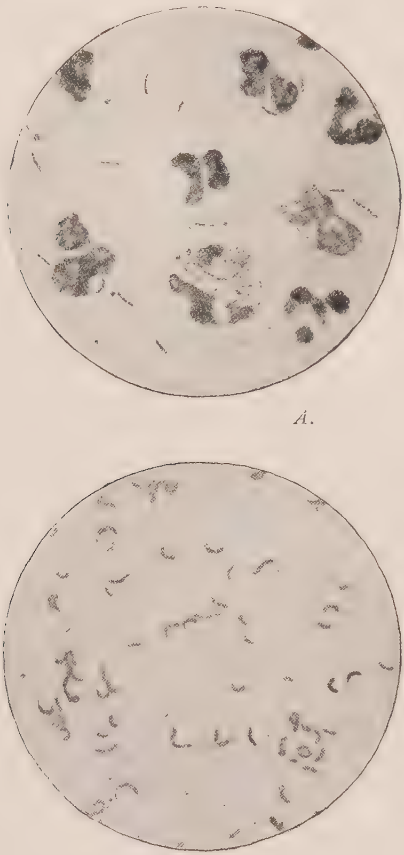


FIG. 77.—The Sundew (*Drosera rotundifolia*).—From Weismann.

digestive juice that reduces to solution the nutritious parts of the victim. The 'peptonized insect extract' thus prepared is absorbed by the lining of the pitcher and constitutes a highly nutritious and stimulating food." The Butterwort (*Pinguicula*) and the Sundew (*Drosera*) are British plants which seize and digest insects by means of contractile and glandular structures on the leaves. The arrangements are essentially the same in the two plants, but are simpler in the Butterwort. Here the violet flowers stand in the middle of a pale green rosette of leaves, which bear a number of little hairs. By these is secreted a sticky fluid which holds small insects that

alight upon them. Then the edges of the leaves curl over the prey and an increased flow of the juice, which is digestive, dissolves the flesh so that it can be absorbed. In the Sundew the end of each leaf is set with tentacles which, from a knob at the top of each, secrete a



A.

B.

Fig. 78.—Bacteria of disease.

A., glanders bacilli ; *B.*, cholera spirilla.

drop of sticky fluid. When an insect is held by some of the tentacles the others bend over to it and it is digested.

Here must be mentioned the cases in which, as in those that have just been described, plants draw nourishment directly from the bodies of particular animals, but in which they do so by *parasitism.* Such organisms may be bacteria (which are perhaps not plants at

all), like those which cause typhoid, leprosy, cholera, tuberculosis, anthrax, diphtheria, the plague, and many other diseases; or, less commonly, fungi, such as those which cause the salmon disease, the disease of silkworms known as "muscardine," and ringworm. They have the great powers of reproduction and the simple structure of other parasites, and they do harm more by the poisonous products which they discharge than by the nutriment

FIG. 79.—The Two-toed Sloth (*Cholœpus*).—From *Marvels of the Animal World*, by W. S. Berridge, F.Z.S., published by Thornton Butterworth Ltd.

which they abstract. Further to discuss them would be beyond the scope of this book.

Finally, there must be recorded at this point the recent discovery that the phosphorescence of certain fishes and cuttlefishes is due to bacteria which, residing in the phosphorescent organs of their host, earn by emitting light the living which they derive from his tissues.

2. In a large number of cases, animals, which may not be herbivorous at all, obtain from plants *concealment or shelter*, by which

they are helped to escape their enemies or to capture prey. Some of these, such as the well-known stick- and leaf-insects and twig-like caterpillars, are wonderfully shaped and coloured to resemble the plants that harbour them, and by their way of standing on the plant make the most of the likeness. The Sloth, by a unique device, carries in its long, grooved hairs green algæ which assimilate its colour to those of its surroundings. These are special cases of the principle of protective resemblance, to which we shall return later. Other animals (birds, ants, etc.) make nests within the bodies of plants, as in the trunks of trees. Whether they be harboured within the plant body or among its members, the animals may avail themselves of the shelter either of living or of dead vegetation. We may note of all these cases that they differ from other relations between members of the animal and vegetable kingdoms in that they do not depend upon the provision of food by one partner for the other.

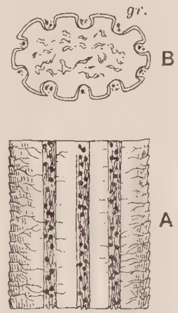


FIG. 80.—Hairs of the two-toed sloth. — After Ridewood.

A., surface view; *B.*, transverse section; *gr.*, grooves in the cuticle, in which the algæ are lodged.

CHAPTER IV

RELATIONS BETWEEN ANIMALS OF DIFFERENT SPECIES

How intricate are the relations between plants and animals will be realized from the outline of them that has been given in the last chapter. We have now to consider some that are even more complex—those, namely, which, in various cases, exist between one animal and another. Regarded as bearing on the struggle of the animal to preserve and increase its kind, these fall into three classes—those of hostility, those of competition, and those of assistance. Relations of each of these kinds may exist between members of different species or of the same species. We will discuss them in turn.

1. Between members of different species, relations of *hostility* may be those of predator and prey or those of parasite and host; and, as we shall see, they may also arise in cases which it is more convenient to class as of competition or of assistance. It will be convenient, moreover, to mention, in connection with relations that are definitely hostile, certain others to which that term can only be applied in its widest sense.

(*a*) The relations between *predator and prey* involve special kinds of behaviour, and the possession of organs suitable for these. The prey may be taken indiscriminately (p. 44), or with discrimination. It may be captured by an animal which remains permanently or temporarily fixed in one place, or drifts; or it may be pursued. (*α*) We have already briefly surveyed the organizations which are adapted for *indiscriminate feeding*. They exist in most of the animals which are permanently or temporarily fixed, and in some others, such as whalebone whales and appendicularian tunicates. (*β*) *Truly predaceous* animals—those that choose their prey—usually seek it by active movements and often pursue it, though they also include many which are fixed or float and have prehensile tentacles, such as most zoophytes. Their habit entrains many striking features of the structure and behaviour of animals. (i) It involves the use by themselves, and often by their prey, of *weapons*, and, since the prey is

FIG. 81.—Red deer fighting.—From *Cassell's Natural History.*

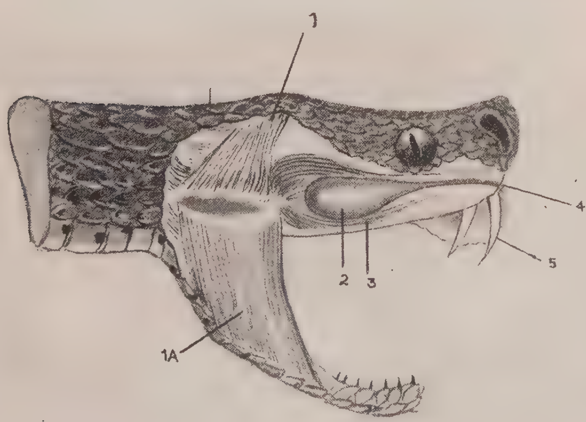


FIG. 82.—A dissection of the head of a Russell's viper.

1 and 1A, the temporo-masseter muscle ; 2, the venom gland ; 3, the external palatine muscle divided to show the gland which is lying between it and the spheno-pterygoid muscle ; 4, the venom duct ; 5, the fang and accessory fang covered by the vagina dentis.

usually of some size, generally also organs for tearing and masticating the food, such as those we have already mentioned. Weapons may be defined as organs used in the endeavour to overcome an enemy, either in offence or in defence. The conflicts which necessitate them are brought about most often by the attempt of an animal to devour another, but also by rivalry for food or mates. Weapons which are used on the offensive against one enemy are, of course, often used also on the defensive against another. Organs used merely for seizing and breaking up food are not weapons; but very often the organs which are used for these purposes serve also as weapons, as, for instance, do teeth and claws in many cases, and they may be

Fig. 83.—The Walrus.—From Flower and Lydekker.
The tusks are the upper canine teeth.

specially developed so as to be serviceable as such. Thus the teeth of snakes are organs for seizing and holding food, but certain of them may possess poison glands and form extremely effective weapons. There are, however, weapons which are not used to seize or break up food, though they may serve other purposes besides combat. The primary use of most of these is defensive, at least as against members of another species. Examples of them are: the tusks of the Elephant, Boar, Musk Deer (Fig. 348), Narwhal, and Walrus, the latter of which serve also to dig up bivalves and to drag the animal over the ice; horns and antlers of various kinds; legs used in kicking, either backward, as by horses, or forwards, as by kangaroos and ostriches; the tails of crocodiles and rays, in the latter spiny and sometimes poisoned; the stings of ants, bees (Fig. 2), and

scorpions; the poison claws of centipedes; and the sharp pleura of the Crawfish or Spiny Lobster (*Palinurus*, Fig. 234). Tusks may be incisor teeth, as in the Elephant and perhaps the Narwhal; or canines, as in

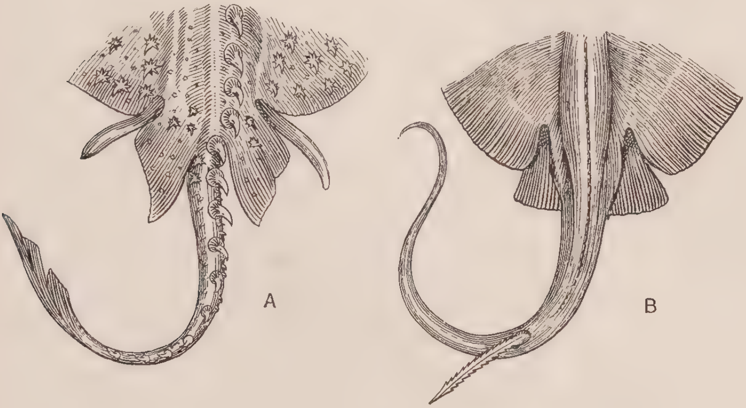


FIG. 84.—The tails of two rays, showing their armature of spines.
A., The Starry Ray (*Raia radiata*); *B.*, the Sting Ray (*Trygon pastinaca*).

the Boar, Walrus, and Musk Deer. In the Boar, Musk Deer, and Narwhal they are possessed by the male only. Horns also are of different kinds. The *antlers* of deer are outgrowths of the frontal

FIG. 85.—The skull of an African elephant.—From the *British Museum (Nat. Hist.) Guide.*

bone, covered during growth with sensitive, vascular, hairy skin. When the growth of the antler is complete the supply of blood to it ceases, the skin dies and peels off leaving the bone bare, and after a time, by a process of absorption near the base, it becomes detached

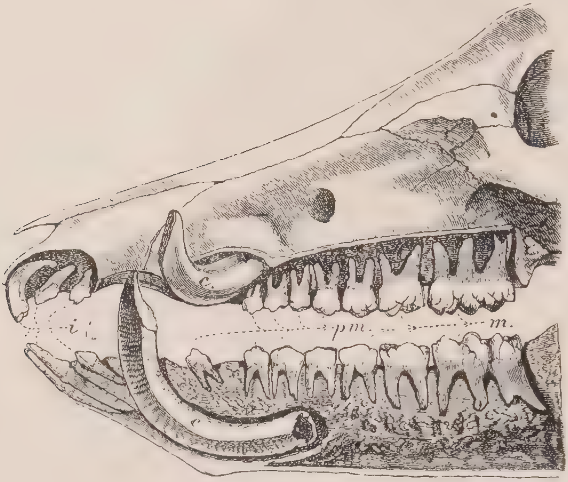


FIG. 86.—Part of the skull of a boar, with the roots of the teeth exposed.—From Flower and Lydekker.

c., canines (tusks); *i.*, incisors; *m.*, molars; *pm.*, premolars.

FIG. 87.—The head of a male of the Red Deer (*Cervus elaphus*), showing the skin ("velvet") which covers the antlers during their growth.—From *Cassell's Natural History*.

from the skull and is shed, leaving a stump upon which the next year's antler grows. In young animals, and in old individuals of a few species, the antler is unbranched. Usually in full grown stags it consists of a stem or " beam " bearing branches known as " tines " or " snags." Save in the Reindeer it is borne by the male only. The Musk Deer, whose weapons are tusks, has no antlers. *True horns* are found in oxen, sheep, and antelopes. These animals

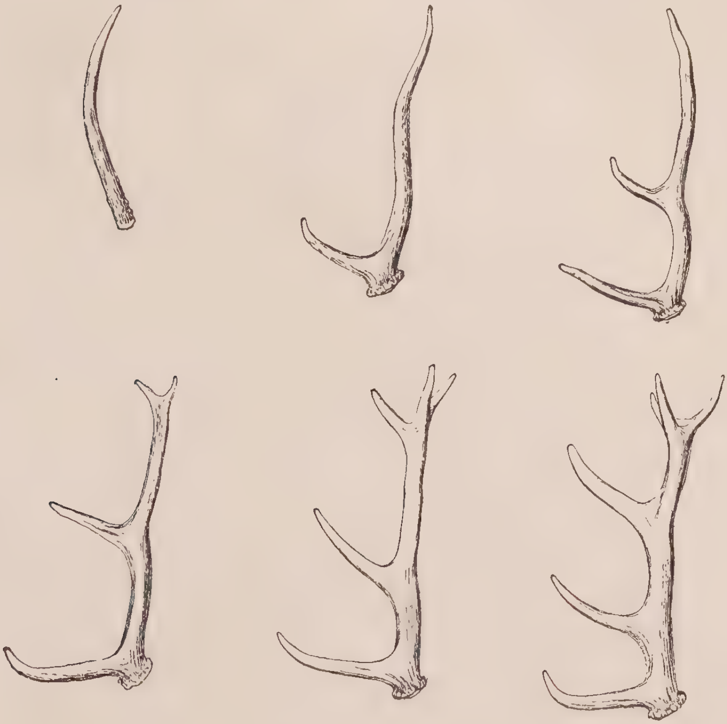


FIG. 88.—The antlers formed by the Red Deer in successive years, showing the addition of a new tine each year.—From Schimkewitsch.

have permanent, conical processes of the frontal bones, into which air spaces continuous with the " frontal sinuses " often extend, sheathed by a case of true horn, developed from the epidermis, which is not shed. Such horns are usually found in both sexes, and they are sometimes larger, though less strong, in the female, which uses them to protect the young. The *horns of rhinoceroses* are purely epidermal structures, fibrous in texture, anchored to the nasal bones.

FIG. 89.—The skull of the Nubian Ibex (*Capra nubiana*), showing the structure of the horns.—From Schimkewitsch.

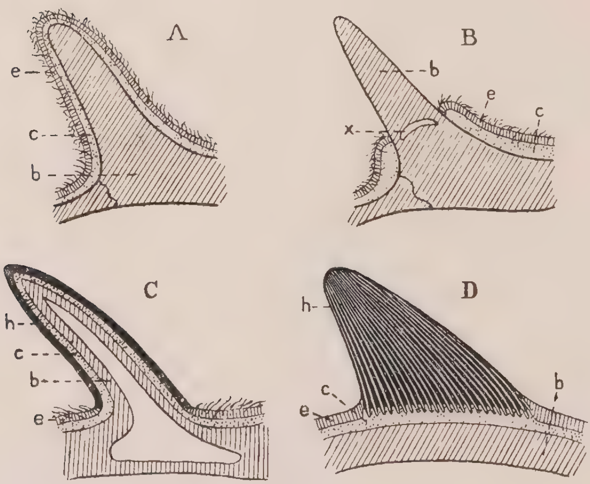


FIG. 90.—Diagrams of the structure of the horns of ungulata.

A., A growing antler ; *B.*, the same fully grown ; *C.*, the horn of an ox ; *D.*, the horn of a rhinoceros.

b., Bone ; *c.*, cutis ; *e.*, epidermis ; *h.*, horn ; *x.*, point at which bone is resorbed in preparation for the shedding of the antler.

(ii) There are, of course, also *purely defensive dispositions*, such as the cuticles of innumerable invertebrates, from protozoa upwards,

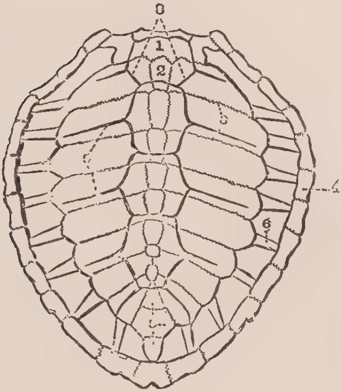


FIG. 91.—A dorsal view of the carapace of a turtle.—From Reynolds.

1, "Nuchal" plate; 2, the first of the row of "neural" plates, fused to the vertebræ; 3, one of the "cortal" plates, fused to the ribs; 4, one of the "marginal" plates; 5, "pygal" plates; 6, rib; 8 and 9, outlines of epidermal plates of "tortoise-shell" by which the foregoing bony plates are covered.

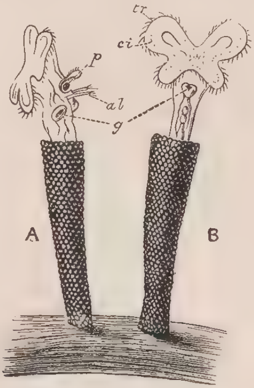


FIG. 92.—*Melicerta*, showing the crown of cilia by which food is gathered, and the house, built of pellets of fæces.—From Hartog, after Joliet.

A., Side view; *B.*, dorsal view. *a.l.*, lateral antennæ; *g.*, gizzard; *p.*, pellet of fæces about to be deposited on edge of tubs; *tr.*, crown of cilia.

and the horny skin of vertebrates (though these coverings must also be of importance in preventing injurious effects of the medium

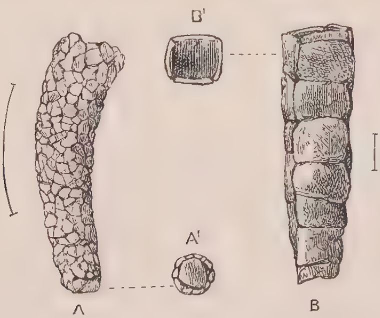


FIG. 93.—Houses of British caddis-fly larvæ.—From Sharp.

A., Of *Odontocerum albicorne*; *A'.*, its termination; *B.*, of *Crunœcia irrorata*; *B'.*, its opening.

upon the organism); the armour of arthropods, various fishes, turtles, armadillos, etc.; the shells of protozoa, molluscs and

brachiopods; the tubes which various worms and other animals construct of secreted materials, organic or calcareous, or of gathered

FIG. 94.—The Common Porcupine (*Hystrix cristata*).—From Flower and Lydekker.

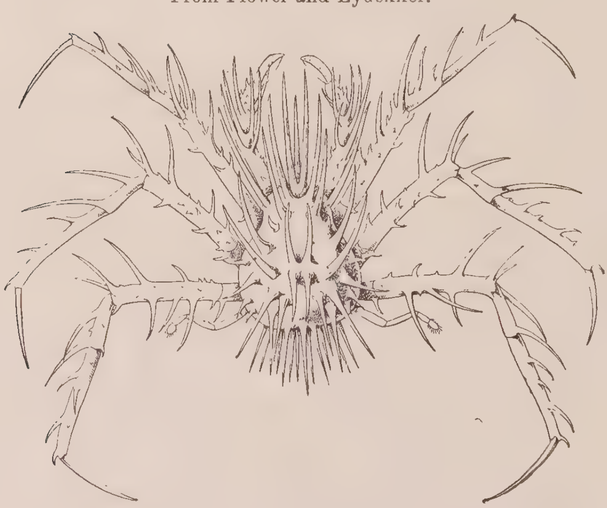


FIG. 95.—*Neolithodes grimaldi*, one of the Lithodidæ, a family of crab-like crustaceans, showing a great development of spines.—From Calman, after Milne-Edwards and Bouvier.

particles (as the rotifer *Melicerta* builds with pellets of its own fæces); the houses which caddis-worms, clothes-moth caterpillars, and other larvæ make and often carry about with them; and the

cocoons of many pupæ. Some of these expedients are probably of as much service by concealment as by protection. There are others which might be described as offensive-defensive. Such are the spines[1] of hedgehogs, porcupines, crabs, and sea-urchins; the little pincers known as "pedicellariæ" upon the skin of star-fishes and sea-urchins; poison secreted in the skin, as in toads, or upon spines, as in various fishes or on some pedicellariæ; stink-glands, as in bugs and the Skunk, and the sticky entangling threads formed by

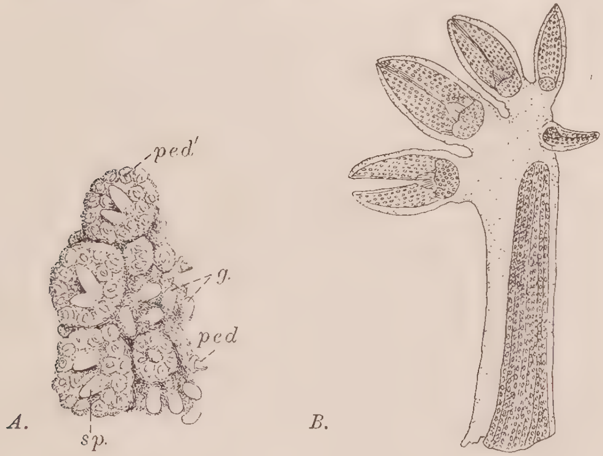


Fig. 96.—Pedicellariæ of a starfish.

A., A small portion of the middle of the aboral surface of an arm; *B.*, one of the adambulacral spines—more highly magnified than *A.*
g., Gills; *ped.*, large simple pedicellariæ of the type found on the adambulacral spines; *ped'.*, small pedicellariæ with crossed blades; *sp.*, spines.
The pedicellariæ of sea-urchins have three blades, and some of them are poisoned.

the "Cuvierian organs" which can be thrown out from the cloaca of holothurians.

(iii) *Locomotion* is used very differently by animals in capturing their prey. Some, such as corals, are permanently fastened in one place. Others, such as *Hydra* and many sea-anemones, move from time to time in search of places where they may await their victims. Others, such as web-spinning spiders and the Praying Mantis, are more active but do not pursue. Others, such as most of the Cats, stalk their prey, or, like the Cheeta, run it down in a short burst, or pursue it untiringly for long distances

[1] The spines of animals serve other purposes besides defence. Those of sea-urchins, for instance, are used for locomotion and for burrowing; and those of many pelagic animals (p. 218), are of use to delay sinking.

as wolves do. Speed is only of use when the prey is chased, but there it is demanded alike of pursuer and pursued. In all cases it depends upon the relation between the weight of the animal, the size and musculature of the organs of locomotion, and the nature of the medium or substratum to which they are applied; but in animals that swim or fly it also depends largely upon the shape of the body. The swiftest birds and fishes are torpedo-shaped, with the greatest width before the middle of the body.

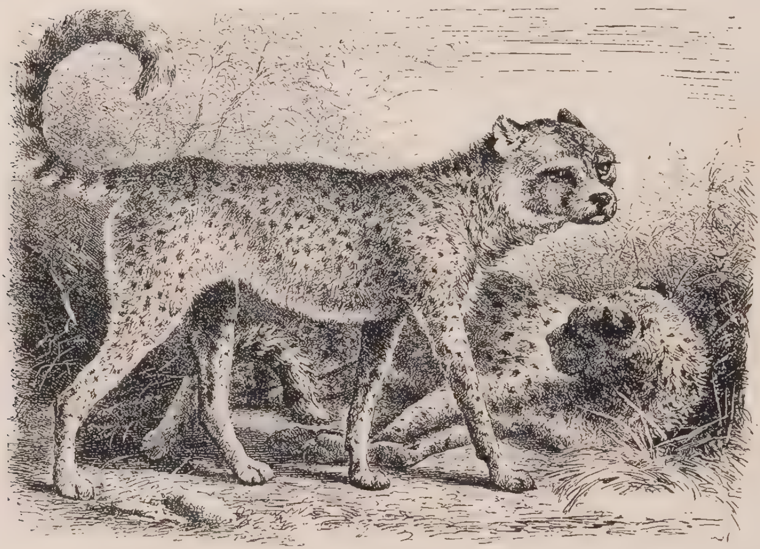


Fig. 97.—The Cheeta or Hunting Leopard (*Cynælurus jubatus*).—From *Cassell's Natural History*.

The animal is built like a greyhound for running, and its claws are very little retractile.

In later pages we shall briefly discuss the use of organs of locomotion in relation to different media and substrata.

(iv) An interesting but not very common expedient of animals that are subject to attack, is that which is known as *Autotomy*, and consists in breaking off a part of the body. This may be left in the grasp of the enemy, while the prey saves itself, or may merely be dispensed with because it is injured. In either case the animal regenerates the lost part. Autotomy is best developed in the Decapod Crustaceans, some of which, such as the China Crab (*Porcellana*), throw off their legs or pincers with extraordinary readiness when they are handled,

though others will only part with a limb that has been injured. The break is brought about by a sharp contraction of muscles, and occurs at a definite place, on the second joint, where an internal partition crosses the limb and prevents loss of blood after the operation. Some centipedes and stick-insects throw off their legs in the same way. Lizards seized by the tail cast it off at a special breaking-place in a vertebra. Various molluscs part with portions of the foot. Starfishes will break off injured arms, and brittle-stars part with these members if they be merely seized. Certain worms will break, when they are injured, into a number of pieces, each of which can regenerate the whole body. *Regeneration*, indeed, is a power possessed in varying degrees by all animals, from *Hydra*, of which a fragment will rebuild the whole body, to the highest vertebrata, which can only heal wounds ; and if from one point of view it is but an aspect of that property by which, in

Fig. 98. - *Peripatus capensis.*—From Sedgwick.

growth and reproduction, all animals strive in all circumstances to maintain and increase their kind, from another it is an adaptation to the struggle against animal foes. In animals which have blood it is preceded by the clotting of that fluid, which seals the vessels and prevents loss. The rebuilding is carried out either by certain of the cells of the connective tissues, or, as in nerves, by the growth of the specialized tissue cells.

(v) *Concealment* is a very important factor in the relations between predaceous animals and their prey. It is used both in escape and in ambush ; and a habit which is to one animal a means of avoiding observation may be to another a mode of pursuit, or may have both these advantages for the same animal. Concealment is attained in various ways. The simplest is that which is known as *shamming dead*, and consists in a stillness that does not attract the eye of a hunter on the look out for moving prey. It is practised by many animals, from spiders to mammalia, and is

often, but not always, accompanied by protective resemblance to the surroundings. *Night habits* are another such expedient, and

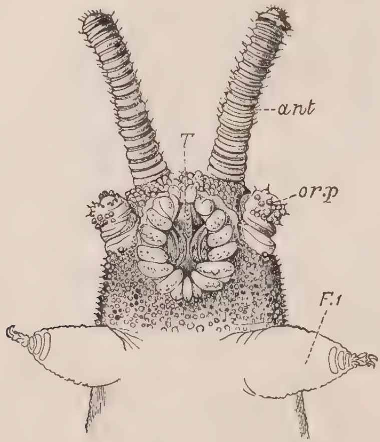


FIG. 99.—A ventral view of the head of *Peripatus capensis*.—From Sedgwick.
ant., Feelers ("antennæ"); *F.1*, first leg; *or.p.*, oral papillæ from which the slime is ejected; *T.*, tongue.

FIG. 100.—The Common Mole (*Talpa europæa*).—From *Cassell's Natural History*.

have, of course, produced a night-hunting series of animals, such as owls and various carnivora. *Hiding* under stones, dead wood,

etc., is another, and is the custom of a large "cryptozoic fauna," some members of which are predaceous upon others which share their shelter with them. Woodlice are typical vegetarian members of the land cryptozoic fauna; centipedes and *Peripatus* are among its carnivorous members; and in any rock pool a host of animals of this habit—fishes, crustaceans, molluscs, worms, etc.—may be found

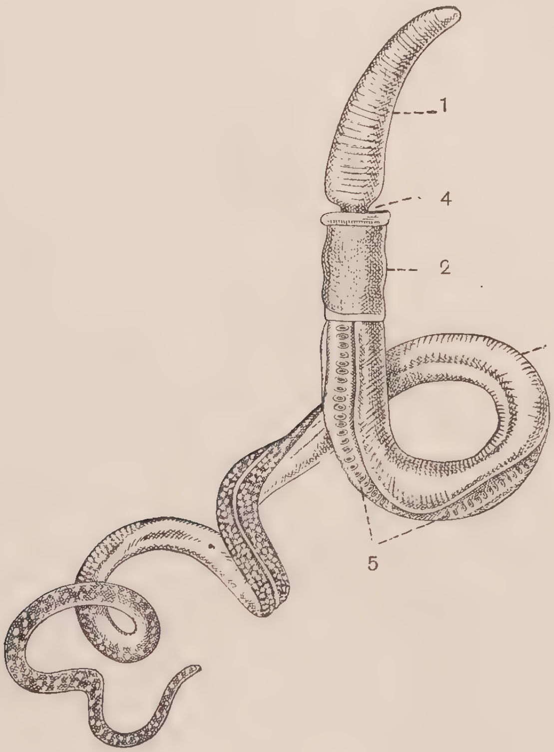


FIG. 101.—*Balanoglossus* (*Dolichoglossus*) *kowalewskyi.*—After Spengel.

1, Proboscis; 2, collar; 3, trunk; 4, mouth; 5, gill slits.

by turning stones. Animals which are cryptozoic by day often issue forth at night to search for food. *Burrowing* is a similar mode of escaping observation; but the animals which practise it are usually more highly modified for it, and their habit affords them not only concealment but also protection from changes of temperature and often food. The Earthworm is a familiar and typical example of an animal that shelters by burrowing, the Mole of one that pursues

such creatures. The body of a burrowing animal is cylindrical, or as nearly so as its ancestral anatomy will permit, and pointed in front. Eyes are reduced or lost, and so are ear-flaps. The actual burrowing may be done either by simply thrusting the end of the body into the substratum, as sometimes by the Earthworm; or by

FIG. 102.—The Mole Cricket (*Gryllotalpa*).—From *Cassell's Natural History*. Note the strong digging feet. The insect frequents meadows, etc., near water, and there seeks its prey (insects, worms, etc.) in burrows which it makes in the soft soil. Its eggs are laid in an underground chamber, and are guarded by the mother till the first moult of the young.

inserting a special organ, as the foot of the Razor-shell and other molluscs, the proboscis of the worm *Balanoglossus*, and the pointed aboral end of the body of the sea-anemone *Edwardsia* (Fig. 235); or by swallowing the soil, as by the Earthworm; or by digging with limbs, which are often strengthened and broadened for the purpose, as in the Mole and the Mole Cricket (*Gryllotalpa*). Animals which burrow into wood generally do so by means of parts around

the mouth. Thus sundry insects, as various beetles and the larva of the Goat Moth (*Cossus ligniperda*, Fig. 56), and crustaceans, as

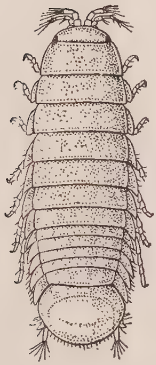


FIG. 103. — The Gribble (*Limnoria lignorum*).

FIG. 104.—Shells of the Piddock (*Pholas dactylus*).—From Calman.
Note the rows of sharp teeth towards the front end (above).

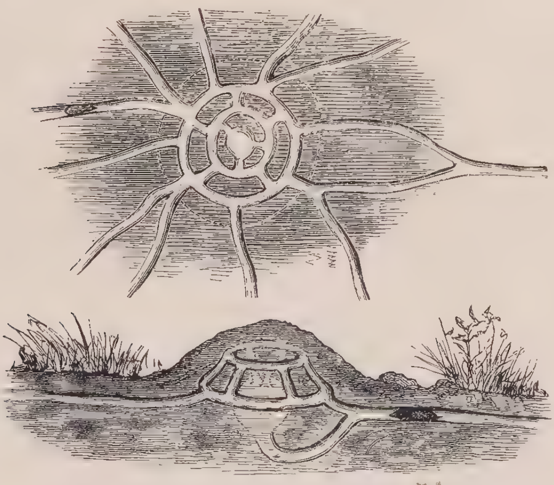


FIG. 105.—Diagrams of a mole's nest and the ways which lead to it. Above, in plan; below, in side view.—From *Cassell's Natural History*.

the Gribble (*Limnoria lignorum*), use the mandibles; and birds, as the Woodpecker, the beak. The Shipworm (*Teredo*), however, bores

by rasping the wood with its shell (Fig. 59), which bears rows of fine, sharp teeth. Among rock-borers, some, as the Piddock (*Pholas*), adopt the method of the Shipworm; while others, as the Date-shell (*Lithophaga*), dissolve the rock, which in their case is always a calcareous one, by secreting an acid. A burrowing animal may merely embed itself in the substratum, as do various crabs and molluscs in sand or mud, but usually it makes a true burrow, however ill-constructed that be. Burrows may be straight or bent, simple or complicated in form, and are often lined. Thus the Shipworm covers the inside of its burrow with a calcareous

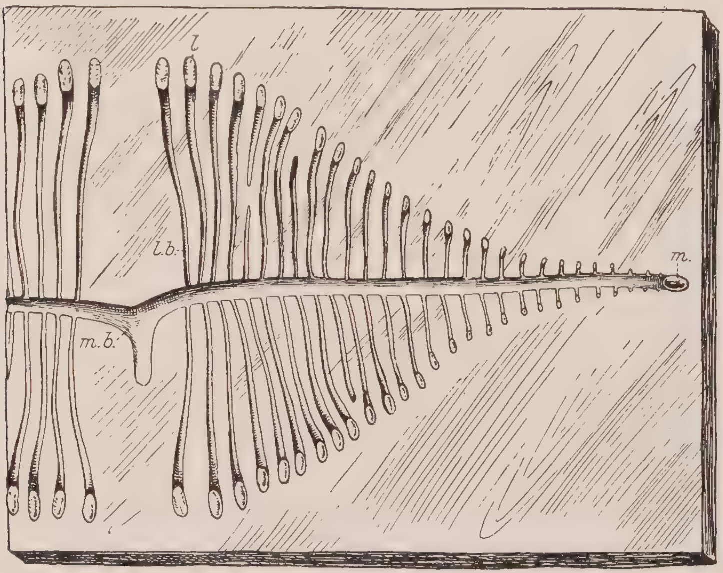


Fig. 106.—Burrows of a wood-boring beetle of the genus *Hylesinus*.
l., Larva; *l.b.*, burrow of larva; *m.*, mother; *m.b.*, burrow of mother.

secretion which forms a shelly tube; some of the burrowing polychæte worms secrete linings of various organic substances, and the Earthworm frequently plasters its burrow with material derived from its castings. When a number of individuals of the same species are boring together, each is usually careful to avoid breaking into the burrows of its fellows, and their galleries may thus come to be regularly arranged. Those of certain beetles are very remarkable in this way. The mother makes a relatively wide tunnel, and as she goes places her eggs in niches along its sides. Each little larva bores for itself a tube at right angles to that of the

PLATE II.

The Green Pit Viper (*Lachesis gramineus*), a widely distributed Oriental tree snake. The animal reaches a length of $2\frac{1}{2}$ feet. Its bite is rarely fatal to adult human beings. It is represented upon a dead branch in order to show clearly a characteristic attitude, but its colour harmonizes with that of its usual leafy surroundings. Note the grasp of the tail, and the head prepared to strike.

mother and parallel with those of its brothers and sisters, and the larval tubes enlarge from one end to the other as their makers grow. A burrowing animal may travel to and fro in its burrow, like the Earthworm or the Mole, or remain lodged at the bottom of it, like the Shipworm. If its food be not obtained in the substratum, or be only partly so obtained, like that of the Earthworm, the animal may leave its hiding-place to feed, may without doing so catch food with appendages, as do some crustaceans (barnacles, crabs, etc.), or may draw it into the burrow by currents like those which are set up by bivalve molluscs and various polychæte worms. Such currents may serve also, or solely, for respiration. In molluscs the siphons are drawn out to subserve them.

Perhaps the most widespread mode of concealment is *resemblance to the surroundings*. This is an extremely attractive and interesting subject, and there is a very large literature devoted to it; but the result of the close study which it has received has been to reveal its problems rather than to solve them. Here we can deal only with its outlines, and in them only with the facts that are not seriously disputed. It is undeniable (*a*) that a vast number of animals exhibit a resemblance to their surroundings, or to some object in them, that is extraordinarily close and is often accompanied by a habit of remaining perfectly still for long periods; and (*b*) that this makes them much more difficult to detect by eye, and must often preserve them from enemies or enable them to steal upon their prey. That it often fails to do so—whether from the sharpness of eye and experience of the enemy, or from its power of smell, or from the necessity which the hiding animal is under of moving from time to time—is as far from disproving its utility as the fact that defensive weapons often fail is from showing their uselessness to their possessors. As to how it has been established, opinions differ widely, and are likely to continue to do so. Resemblance to the surroundings may consist in a *general* harmony of the appearance of the animal with that of its neighbourhood, so that it becomes inconspicuous, or in a *special* likeness to objects of a particular kind, so that it is liable to be mistaken for one of them. Often-cited examples of *general resemblance* to the surroundings are the whiteness of the inhabitants of snowfields (p. 301), the sandy colour of those of deserts (p. 299), the striped or dappled markings of those that live amid vegetation, and the reversed shading by which many animals offset the shadow on their under sides by pale colour and the high light above by dark so that their shape is lost. So are the green colour of numerous insects, tree-frogs, etc., which spend their lives on plants, and the bright hues in

Fig. 107.—The Australian Sea-horse (*Phyllopteryx eques*).—From Boulenger.

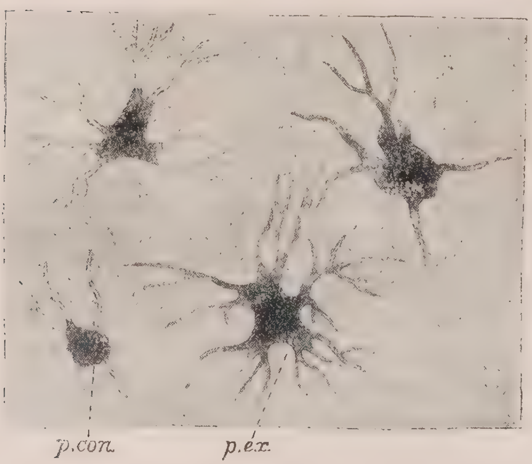


Fig. 108.—Pigment cells in the skin of a frog, seen through the epidermis.

p.con., Cell with pigment contracted; *p.ex.*, cell with pigment extending into the processes.

which many sea-animals resemble the zoophytes, crinoids, etc., upon which they dwell. Sometimes to the colour resemblance of such animals there is added a general resemblance brought about by the form of the body, as in the Australian Sea-horse (*Phyllopteryx*), which is not only coloured with the brown shade of the seaweed to which it clings by its tail, but has its spines converted into streamers which resemble those of the weed. In a number of cases animals have the power of changing their colour by expanding and contracting pigment cells in the skin,[1] and in this way they take on the colouring of their surroundings. The Chameleon is a well-known instance

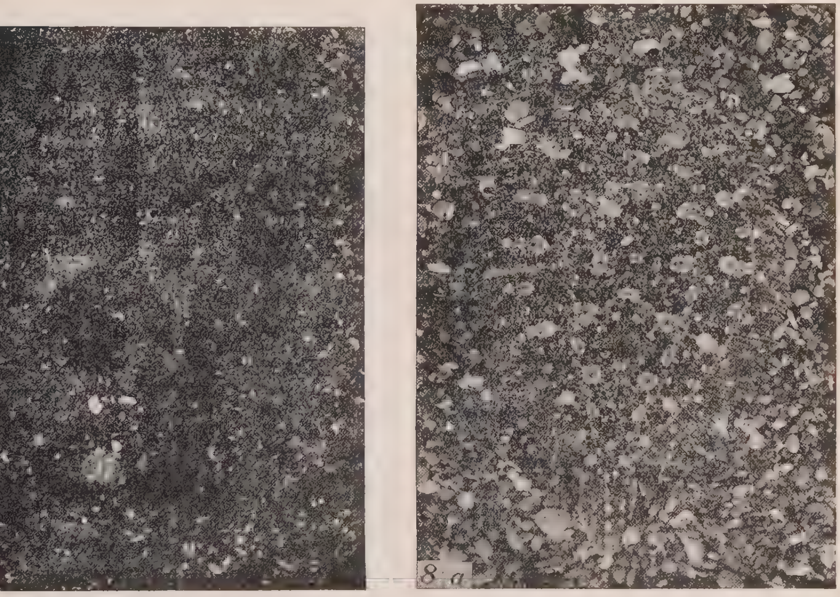


FIG. 109.—Two small flat-fishes of the species *Rhomboidichthys podas*, photographed on ground of natural composition to which they have assimilated themselves by colour change.—From Bayliss, after Sumner.

of this, and it is found also in the Common Frog, and very well-developed in flat fishes such as the Plaice and Flounder, whose mottling takes on not merely the shades of colour, but even the coarseness of pattern of the sand or gravel on which they lie. Cuttle-fish, prawns, and many other creatures have this power of colour change. It is found to be effected usually through the eye and

[1] Or rather, in most cases (frogs, prawns, etc.) by the spreading and withdrawing of the pigment in the branches of cells in which it is contained. But cuttlefishes actually expand the cells.

nervous system, but sometimes by the direct action of the light upon the colour cells, as in certain of the colour changes of prawns.

Special resemblances are even more remarkable than the

Fig. 110.—The female of a leaf-insect of the genus *Phyllium* —From Romanes.

general ones, and include a larger element of resemblance in form. We have already cited the well-known leaf- and stick-insects and caterpillars, which resemble leaves and twigs alike by their colour

Fig. 111.—A stick-insect.—From Romanes.

and shape and by the attitudes which they take up upon plants. The leaf- and stick-insects are orthoptera of warm climates. Most of them are vegetarian, but the Praying Insects (*Mantidæ*) use their disguise to conceal them from other insects, which they capture

with their forelegs held in the "attitude of prayer." The stick-caterpillars are among the "looper" larvæ of the moths of the Geometræ, and, as is well known, a number of them are British. That of the Brimstone Moth (*Rumia cratægata*) is a common and very perfect example. Poulton says of this creature: "It will be observed that some of the twigs are slightly bent in the middle, and that a projection is placed on the angle: these appearances are exactly reproduced in the larva. . . . The smaller branches of the hawthorn are partially covered by a thin superficial layer of a bluish-grey colour (the cuticle), while the deeper layers beneath are brown or green, or mixed brown and green; these tints become visible over a large part of the surface owing to the breaking away of the thin layer. Hence the colour of the branches is brown or green mottled with grey; and not only are these the exact tints of the larva, but the way in which the colours are blended is precisely similar in the animal and in the plant." Another well-known and often quoted instance is that of the Leaf Butterflies (*Kallima*) of the tropics, which when they are on the wing are conspicuous by the bright orange and purple markings of the upper sides of the wings, but when they come to rest instantly disappear because the wings are then closed so as to show only the under side, which both in form and in marking closely resemble withered leaves, among which the insects settle, showing not only midrib and veins, but even mildew marks and transparent patches which simulate insect-bites. The resemblance of the common Buff-tip Moth (*Pygæra bucephala*) to a thickened twig, which has snapped so as to show the yellowish wood, is almost as remarkable. To quote only three more from thousands of cases, the little crab *Huenia proteus*, whose shape and colour vary with the weed among which it lives, often mimics exactly the segments of the *Halimeda* weed upon which it is sitting; a spider described by H. O. Forbes imitates exactly a bird's dropping, and thereby is enabled to capture certain butterflies to which such droppings are food; and other spiders, resembling by a remarkable transformation of their bodies species of ants, live among the latter, and obtain the immunity from many enemies of insects which is enjoyed by these creatures.

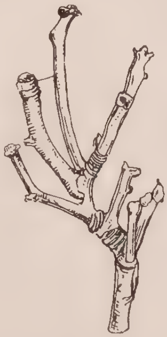


Fig. 112.—A larva of the brimstone moth resting upon a hawthorn twig.—From Poulton.

This last instance is one of a very large number especially conspicuous among butterflies but found also in many other

orders, in which animals resemble others to which they are not so closely related as the resemblance would suggest. The name *mimicry* is usually reserved for these resemblances. It has been held that in such cases one of the two animals is distasteful or dangerous, and that predaceous animals know it to be so and recognize it and therefore avoid both it and its imitator. Thus the butterflies of the families Danaidæ and Heliconidæ, found

FIG. 113.—*Kallima*, in flight, and settled on a twig with closed wings.—From *Cassell's Natural History*.

chiefly in warm countries, whose members have been proved to be distasteful to insect-eating animals, are closely resembled by certain species of other families, notably the Pieridæ (whites) and Papilionidæ (Swallowtails), which are not distasteful, and except for these imitative species are quite unlike the Danaidæ and Heliconidæ. The resemblance between the Muslin Moth and the distasteful White Ermine Moth of this country is said to belong to the same

PLATE III.

The Banded Krait (*Bungarus fasciatus*), a brilliantly-coloured and very poisonous snake, with a wide distribution in S. Asia.

category. In some of these cases the facts—the distastefulness of one of the species, its greater abundance than the other, and the presence of enemies—appear to have been established. In others there are difficulties in these and other respects, and thus doubt is cast upon the cases which seemed to have been established. The matter is the subject of much controversy, and we shall not dwell upon it here. Closely related to it is the theory of *warning colours*, which holds that the conspicuous markings of wasps, poisonous snakes, distasteful insects such as the Currant Moth, and other

FIG. 114.—A sprig of *Halimeda* weed with a specimen of *Huenia proteus*, showing the likeness of the latter to the segments of the fronds of the weed.

FIG. 115.—*Synageles picata*, an ant-like spider.—From Peckham.

The first pair of legs is held in a position in which it adds to the general resemblance of the body to that of an ant by simulating a pair of antennæ.

creatures are of use to the animals that bear them by warning others not to attack them. This also has been disputed, partly on the ground that not all such creatures are conspicuously marked, but it seems likely that it has a basis in fact. All predatory animals distinguish between those others that are safe prey and those that are not. It is hard to believe that conspicuousness does not help to make the distinction.

A very effectual though rather rare mode of concealment is that which is known as *masking*. It is perhaps best seen in the various kinds of spider-crabs which, living on or among seaweed, cover their

bodies with pieces of the growths around them. Bateson gives the following account of the masking of one of these creatures. "The crab takes a piece of weed in his two chelæ, and, neither snatching nor biting it, deliberately tears it across, as a man tears paper with his hands. He then puts one end of it into his mouth and after chewing it up, presumably to soften it [it is made sticky by the secretion of certain glands], takes it out in the chelæ and rubs it firmly on his head or legs until it is caught by the peculiar curved

Fig. 116.—*Methona pisidii* (Heliconidæ), and *Leptalis orise* (Pieridæ). —From Wallace.

hairs which cover them. If the piece of weed is not caught by the hairs, the crab puts it back in his mouth and chews it up again. The whole proceeding is most human and purposeful. Many substances, as hydroids, sponges, polyzoa, and weeds of many kinds and colours are thus used." If the crab be placed in a tank which contains shingle but no weed, it will sometimes scatter small stones upon its back. The whelks of the genus *Xenophorus* conceal their shell by cementing to it other empty shells, bits of coral, etc. ;

some sea-urchins will pile stones upon their bodies or hold over them the fronds of seaweed; female centipedes roll their sticky eggs in the soil until they are disguised by a covering of earth (p. 122);

FIG. 117.—The spider-crab *Maia squinado*, dressed in fragments of weed.—From Calman.

FIG. 118.—Pupæ of a flea, showing gritty particles attached to the pupa cases.—After Bacot, from the *Journ. of Hygiene.* (Photo by Tonge.)

and the gritty particles which adhere to the cocoons of various insects, such as fleas, when they are not accidental, serve for concealment as much as for strengthening. Finally, we may add the

ink-squirting of cuttlefishes to the list of means of escape by concealment.

(vi) It must be noted that many of the phenomena that we shall consider below, under the head of relations of assistance, might from another point of view be regarded as expedients in the struggle between predator and prey.

(*b*) The relations between *parasite and host* vary enormously, both in kind and in closeness, in different cases. A parasitic organism is one which, living on or in some other organism, and deriving food or some other benefit from it, in some way harms it. The benefit accruing to a parasite is nearly always nutriment, but it may also, or only, consist in transport or shelter. The harm which it does may consist in damage to tissues, abstraction of nutriment, or the excretion of poisonous substances. The series of

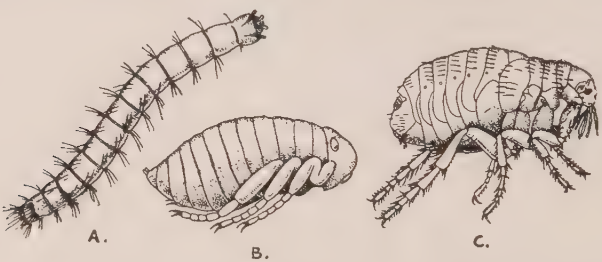


FIG. 119.—The Common Flea (*Pulex irritans*).
A., larva; *B.*, pupa; *C.*, adult.

such cases ranges from some which hardly differ from the preying of a small animal upon a large one—there is no great unlikeness, for instance, between the habits of a mosquito and those of a flea—to internal parasitism of the most intimate kind; and from others that are not unlike the harmless associations of organisms which we shall presently describe as "synœcy," to the causing of fatal diseases. True parasitism does not occur in the Protochordata, Echinodermata, Brachiopoda, and Polyzoa. In some other groups of animals, as the Mollusca, Annelida, and Cœlenterata it is rare. In the Crustacea, Insecta, Flat-worms and Protozoa it is common. In the Nematoda it is the habit of most species. From *Amœba* to Man there is probably no animal which is not attacked by some parasite; and, as many species of parasites are confined to one host, it is probable that parasitic animals are not greatly inferior in numbers to all the others together, though their habits prevent this fact from being generally realized.

Parasites may be *external* or *internal* to their hosts. External

parasites include such creatures as bugs, fleas, lice, ticks, some leeches, and numerous crustacean "fish-lice" (Figs. 122, 197), whose nutriment is derived from their host's body; others, like the Pea Crab (*Pinnotheres*) and the Oyster Prawn (*Conchodytes*), which shelter within the shell of bivalve molluscs, and the amphipod crustacean *Hyperia* which lives within the umbrella of a jellyfish, whose food is stolen from that of their host; and yet others, like the Boring Sponge (*Cliona*) when it attacks the shell of living molluscs, and perhaps certain of the barnacles that live upon whales (p. 115), which derive no nourishment from their host, but injure it in finding shelter upon it. They live upon surfaces exposed to air or to water, and are

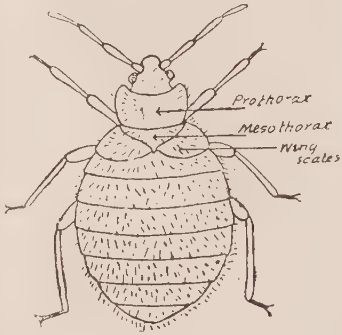


FIG. 120.—The Bed Bug (*Acanthia lectularia*).—From Murray, after Butler.

FIG. 121.—The Head-louse (*Pediculus capitis*), male. A cleared preparation, showing the gut distended with blood. Note the claws for clinging to hairs.—(From a photo by Dr. J. Bell.)

rarely as highly modified from the condition of free-living animals as are those that live within the bodies of their hosts. Internal parasites must be looked upon not merely as presenting a case

of relation of organisms, but as a "fauna," with its own medium, substratum, and relations to temperature and light; and we shall defer separate consideration of them to a later chapter.

Parasites in general enjoy shelter and plentiful food, which, moreover, needs no hunting and is generally easy of digestion. On the other hand, they are related to a very special habitat, which is scattered and therefore needs finding, and is often in motion, or specially defended against them, so that it is hard for them to get or to maintain a foothold; and as a rule their habits when they are settled are of necessity sluggish and

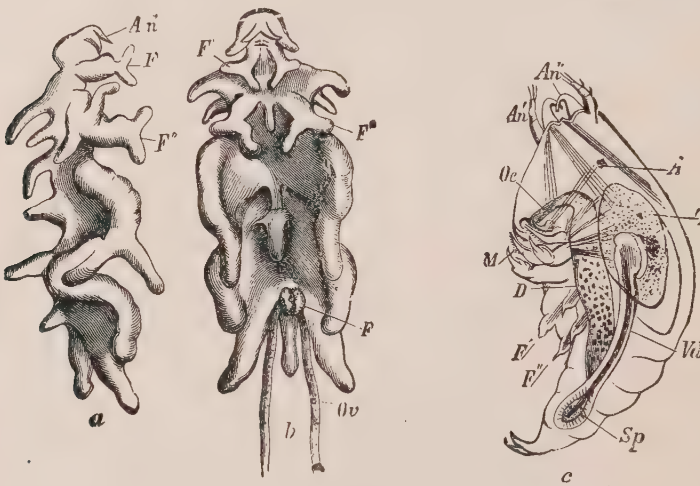


FIG. 122.—*Chondracanthus gibbosus.*—From Claus.

a., Female, from the side; *b.*, female in ventral view, with adhering males; *c.*, male, strongly magnified.

A., Eye; *An'.*, antennules; *An''*, antennæ used for attachment; *D.*, intestines; *F'.*, *F''.*, the two pairs of thoracic limbs; *M.*, mouth parts; *Oe.*, œsophagus; *Ov.*, egg-tubes; *Sp.*, spermatophore; *T.*, testis; *Vd.*, vas deferens.

not compatible with an active search for mates. They have in correspondence with those conditions certain general characteristics, though their mode of life is so varied that there is hardly one of these that does not make exceptions among them. Briefly stated, such characteristics are: (i) a reduction, in the parasitic stage, of the organs of special sense and of the nervous system; (ii) very commonly, though not remarkably in those which move from host to host, as fleas, or live freely in cavities of the body, as ciliates of the gut, a reduction of the organs of locomotion; it is in these two features that the so-called "degeneracy" of parasites chiefly consists; (iii) often, though not in those which, like the

bladder-worm stage of a tapeworm, live embedded in tissues, means of clinging to the body of the host, such as hooks or suckers, upon limbs or elsewhere; (iv) often, especially in external parasites, special organs for piercing the tissues of the host and sucking his fluids; (v) a high rate of reproduction, which is supported by the good supply of nourishment and the small expenditure of energy, and offsets the high death-rate among the young owing to failure to find a host; (vi) a special distributive stage, which may be a larva, as the nauplius of the Parasitic Barnacles or Rhizocephala (*Sacculina*, etc.), or an alternate generation, as in the life-history of the Liver Fluke, and may be active, well provided with organs of locomotion, or passive, as the hard-shelled eggs of parasitic worms, etc.; (vii) often parthenogenesis, whereby the search for a mate is rendered unnecessary, or hermaphroditism, which, if it be self-fertilizing (which does not often happen), has the same advantage as parthenogenesis, and if not has at least that of enabling one meeting to fertilize two individuals. Sometimes, as in various crustacea, there is a young adult pairing stage, after which the female becomes parasitic (p. 171).

An animal may be parasitic only in the adult stage, like many fish lice; or only when it is young, like the Freshwater Mussels (*Anodonta*, Fig. 47), and the Rain Worm (*Mermis*); or may be free only as an egg, like the nematode *Ascaris*; or may pass the whole of its life either with one species of host, like the Itch Mite (*Sarcoptes*), and often the worm *Trichinella*, or with two, like the Malaria Parasite, which, in different stages, infests man and mosquitoes, entering the latter direct from the first host when the insects suck his blood.

The life-histories of parasites are often exceedingly complicated. We can here only refer to such cases as those of the plant-louse *Phylloxera*, the crustacean *Lernæa* (p. 171), the Liver Fluke, and the Malaria Parasite (Figs. 420, 421), which are more eventful and intricate than the metamorphoses of any non-parasitic animal, except perhaps certain protozoa, such as *Arcella*.

Against the attacks of external parasites an animal may be protected by a tough, armoured, or slippery skin, by the secretion of mucus which carries off the settling larvæ, by a habit of scratching or otherwise removing the parasite, and perhaps sometimes by some poisonous quality of the blood. Against internal parasites it has other defences with which we shall deal later. It is not in the interest of a species of parasite so completely to overcome these precautions as to destroy its host, and consequently most parasites have arrived at a kind of equilibrium with the animals they infest. Probably it is only parasites that are invading a new species of victim which,

not having attained this equilibrium, are really dangerous to their hosts. This is seen, for instance, in the higher death-rate of strange races in any country from its native diseases.

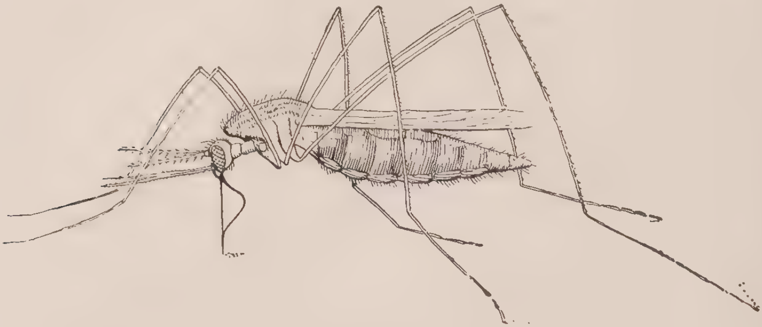


FIG. 123.—A mosquito, sucking blood.—After Nuttall and Shipley.
The curved line under the head is the labium.

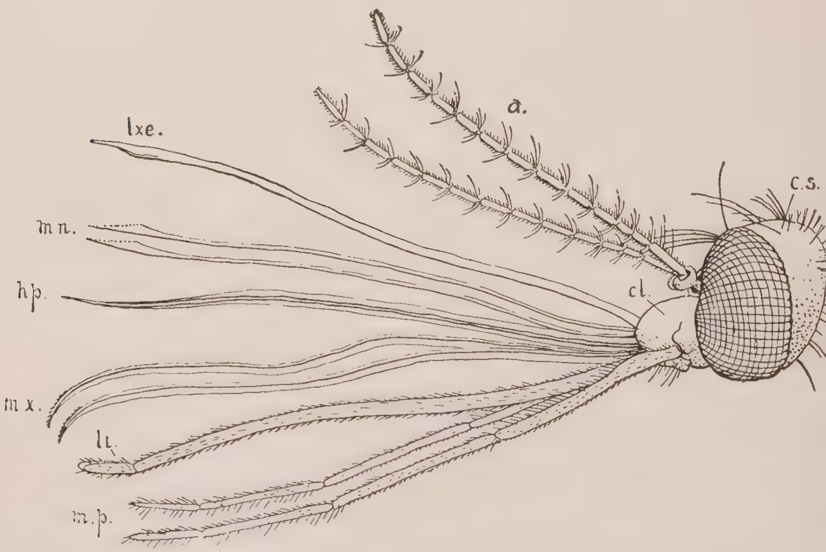


FIG. 124.—The mouth-parts of a mosquito.—After Nuttall and Shipley.
a., Antennæ; *lxe.*, labrum and epipharynx; *mn.*, mandibles; *hp.*, hypopharynx; *mx.*, first maxillæ; *li.*, labium; *m.p.*, maxillary palps; *cl.*, clypeus; *c.s.*, head scales.

A very striking kind of parasitism is that in which the host is itself a parasite, so that the well-known rhyme about "greater fleas" and "lesser fleas" is justified. This is known as *Hyperparasitism*.

The isopods of the family Cryptoniscidæ, for instance, are parasitic upon the degenerate barnacles (*Rhizocephala*) which themselves infest crabs. Among insects, where this phenomenon is not uncommon, there may be a third and even a fourth stage of parasitism. Thus the Aphides (themselves parasitic upon plants) are infested by the larvæ of ichneumon flies of the Braconidæ. The ichneumon larva is in turn liable to contain the larva of a cynipid, and it appears that the larvæ of a third family of Hymenoptera, the Proctotrypidæ, which are ecto-hyperparasites of the Braconidæ, may also destroy the cynipid endo-parasites.

(*c*) Out of either of the relations of hostility which we have now discussed, there may arise a further relation in which one party

Fig. 125.—The Tsetse fly (*Glossina*).

Species of this genus infect man and animals with protozoan parasites of the genus *Trypanosoma*, causing sleeping sickness, cattle sickness, etc.

is *indirectly harmful* to the other, rather than in the strict sense hostile. This happens when an animal either infects or is infected by its prey or host with a parasitic organism, as blood-sucking insects may infect Man. Often, as in the case of the Mosquito, the injury is reciprocal. The same state of affairs may arise between animals which are otherwise indifferent to one another, as when the House Fly spreads epidemics by contaminating food, or a blood-sucking insect which does not attack Man affects his food-supply by conveying a disease to his cattle.

(*d*) Here may be mentioned the *scavenging animals* to which allusion has already been made (p. 11). Their relation to the organisms upon which they depend for their food is logically to be regarded as one in which they receive assistance without either

conferring a benefit or inflicting an injury; but in their effect upon the bodies upon which they feed they cause destruction after the manner of hostile animals. Scavengers are perhaps on the whole more like parasites than predators; but according to their size, and to whether they merely visit or pass their existence upon or in their food, their mode of life approaches one or other of these types. Beyond the source of their food, they have not much in common as a class.

2. Relations of *competition* between animals are much discussed in works upon natural selection, on account of the effect which, after long periods of time, they are supposed to have upon the characters of the race. From a point of view that is not concerned with evolution they have less importance. It is true that, in a world which by their great powers of reproduction animals keep fully populated, there is competition for the necessities of life—for food, for water, for foothold, for hiding and nesting places, sometimes, perhaps, for oxygen—and that the success of an animal or a species depends upon its relative efficiency in obtaining these. But the converse kind of "competition"—that to escape from enemies—does not press upon the individual at all. In that devil-take-the-hindmost race, the more the competitors the safer each of them is. Yet the student of evolution, who watches the weeding out of the unfit, is as interested in this rivalry as in the other. Two things may be noted concerning the competition for food, etc. In the first place, for the individual the most dangerous rivals are the members of its own species, since no other organisms have so nearly the same needs; but the competition of species is not necessarily keenest between those that are most nearly related. Two caterpillars of allied species may feed upon different plants where each, in bad seasons, may be endangered by the competition of quite unrelated organisms, but is safe from that of its congeners. In the second place, while competitors are usually only indirectly injurious to one another, they may, as when they quarrel over a carcase, become actively hostile to one another.

3. Relations of *assistance* between animals of different species, like the well-known partnerships of the ant and the plant-louse, or the hermit crab and the anemone, are suspected to exist in a long and varied series of cases in which such species are found constantly associated in Nature. It must be admitted, however, that in the absence of reliable knowledge we have no certainty about many of these. Strange partnerships and "happy families" are attractive subjects for speculation, and it is possible that some of them have not the significance that has been supposed. Yet

there are many in which the association is so close, and is accompanied by bodily features which are so evidently adapted to further it, that it is impossible to doubt that the life of one or both partners is modified by it. Non-parasitic partnerships between animals fall into three classes—those in which the assistance is mutual; those in which, while neither partner is harmed, only one derives benefit from the association; and those in which, in benefiting itself, one partner puts the other at a disadvantage. In each class there are associations of which the members are free and others in which one member resides upon the body of the other. The second class merges gradually into parasitism in a series of cases. The third differs from parasitism only in that the benefited partner does not dwell in or upon the other. A few examples of each class may be mentioned. (i) To the first class, known as *Mutualism* or *Commensalism*,[1] may be assigned the alleged partnership between ostriches and zebras, which, living in common herds, are said to avail themselves, in becoming aware of enemies, of the superior sense of sight of the ostrich and the powers of scent possessed by the zebras. If that be doubtful, it cannot be denied that mutual benefit is derived from the association between man and his domestic animals. As in other human affairs, the fact that this is brought about by intelligent action is apt to blind us to its aspect as one of the processes of Nature. Yet such it is; and the arrangement has had the usual result of affecting the evolution of one at least of the parties to it, as may be seen in the difference between domestic animals and related wild species. Various birds search for parasites upon the bodies of other animals, and in this, while they obtain food for themselves, are of service to the hosts. Thus the Crocodile Bird (*Pluvianus ægyptius*) removes leeches, and perhaps fragments of food that would otherwise decay, from the mouth of the Crocodile, which, with its jaws open, permits the search. The Oxpecker (*Buphaga africana*), riding upon the backs of cattle and rhinoceroses, devours the ticks, etc., by which they are infested; and the Common Starling may sometimes be seen to perform the same office for sheep. In the partnerships between various ants and plant-lice (*Aphis*), the lice are protected and their eggs sheltered in winter by the ants in return for the excess of the easily procured food which oozes from the hinder end of their alimentary canals. Some of them live in the nests of the ants, feeding on the roots of plants. Of others Lord Avebury gives the following description: "Here are aphides, not

[1] The latter of these names should in strictness be reserved for cases where food is shared, and should be applied also to cases like that of the Pea Crab, which are best regarded as instances of parasitism.

living in the ants' nests, but outside, on the leaf-stalks of plants. The eggs are laid early in October on the food-plant of the insect. They are of no direct use to the ants, yet they are not left where they are laid, exposed to the severity of the weather and to innumerable dangers, but are brought into the nests by the ants, and tended by them with the utmost care through the long winter months until the following March, when the young ones are brought out and again placed on the young shoots." A familiar instance of commensalism between sea animals is that of hermit crabs and anemones. The Hermit Crabs are crustaceans related to the Crayfish and Lobster, but with the abdomen soft, owing to the thinness of its cuticle, and twisted so that it will fit into the

FIG. 126.—Sea-anemones on the shell of a hermit crab.

empty shells of whelks and similar molluscs. They anchor themselves into the shells by means of the limbs of the sixth abdominal segment, and when they are attacked they withdraw into the shell by the contraction of a muscle in the abdomen; but often this does not save them from being eaten by fishes, of which they are a favourite food. They are very active and are constantly travelling in search of food, dragging about their shells with them. Sea-anemones, owing to their stinging cells, are distasteful to fishes, as is shown by the fact that they will not serve for bait. They cannot pursue their food, but must wait till it comes within reach of their tentacles. Now certain kinds of anemones are found on the shells of hermit crabs. Here they are never molested by the owner of the shell, and benefit by the constant change of feeding-ground and by fragments of food which are let fall by the hermit crab, to

obtain which some of them take up a particular attitude, standing with the mouth on the lower side of the shell which they enwrap with their enlarged base. In return the crab obtains protection from fish, which are kept from eating it by the stinging power of the anemone. It is alleged that when the crab removes to a new shell it takes the anemone with it, detaching it and placing it again in position with its pincers. With the Cloak Anemone (*Adamsia*), however, which enwraps the shell, this would appear to be unnecessary, for it grows with the crab, and extending beyond the mouth of the shell enlarges the shelter. After a time it almost

FIG. 127.—A deep-sea hermit crab (*Parapagurus pilosimanus*) sheltered by a colony of *Epizoanthus*.—From Calman.

entirely dissolves the shell by some action of its base, and remains enclosing the crab as a cloak. Deep-sea hermit crabs are known with similar habitations formed by colonies of anemones (*Epizoanthus*), and these are sometimes established without any shell. The hydroid zoophyte *Hydractinia* also forms by its colonies the covering of the shells of hermit crabs. In other cases, on our own coasts and elsewhere, a sponge, which like anemones is a distasteful organism, settling on the shell of a little hermit crab, grows with the crab and protects it. Since the sponge cannot share the food of the crab, the advantage which it derives from the partnership

is presumably that of being carried to new waters for its own fishing. To many of these associations there is added a third partner in a worm of the genus *Nereis*. It has been supposed that this creature benefits the crab by keeping clean the interior of the shell. Otherwise, since it will steal food with its jaws from the very pincers of the crab, it must be regarded as a parasite.

(ii) Associations between animals in which neither party takes harm but only one is benefited are known as *Synœcy*. The best-known cases of this kind are those in which small animals accompany a larger one in order to devour fragments of its food, or prey, which it has terrified. Thus the Pilot-Fish (*Naucrates ductor*) swims with sharks, and the Sucker Fish (*Echeneis remora*) attaches itself to them or to whales or turtles by a sucker on the top of its head. Both these species will accompany ships and consume food that is thrown overboard. Small birds sometimes nest near a large species, in order to benefit by its guardianship of its own young. Grakles (*Guiscalus*), for instance, build in the interstices of the nest of the Osprey (Fig. 17), whose fish diet probably keeps it harmless to small birds. In synœcy, as in mutualism, zoophytes are often a defence to other organisms. The bushy growths of coral stocks shelter in their interstices a whole fauna of animals of many species and various classes—worms, brittle-stars, molluscs, little fishes, and, above all, prawns and crabs, which live among the branches, finding there shelter and protection by the stings with which the polyps are armed. The large tropical anemones of the genus *Discosoma* harbour in a similar way certain prawns and fishes which keep within the protection of the stinging-cells of the zoophyte, and will at a pinch even enter its mouth and take refuge within its body. In our own waters, little fishes, mostly the young of the Cod family (*Gadidæ*), hover in the zone of defence provided by the tentacles of a large jelly-fish, and when frightened flee under its "umbrella," and, it is said, shelter in the subgenital pouches. In all these cases the sheltering animals must be in some way—perhaps by means of skilful movements—immune to the stings which keep at a distance their enemies. They are often coloured to resemble their hosts. Rather more intimate is the association of the small fish *Fierasfer* with the Trepangs—sea cucumbers (*Holothuroidea*) of the warmer seas. Here there are no stinging tentacles, and the fish spends most of its time within the cloaca of the holothurian, coming out at times to feed, and again retiring to shelter. In others cases the associates are permanently united. The bivalve mollusc *Modiolaria* (Fig. 236) is embedded in the tissue of *Ascidia* and other simple ascidians, with the hinder end, which

FIG. 128.—A view at low water on the great barrier reef of Australia, showing branching coral growths.—From Saville Kent.

bears the openings of its siphons, protruding. It is harmless. The female of the crab *Hapalocarcinus*, living on the branches of

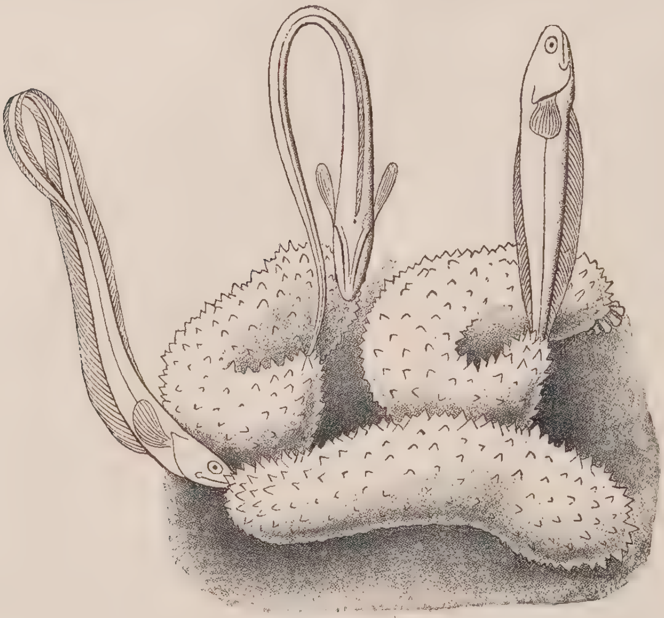


FIG. 129.—*Fierasfer acus*, with the holothurians it inhabits.—From Boulenger, after Emery.

coral stocks, and sitting always in one place, stimulates, by her gill currents, the growth of the coral around her, till she is enclosed in

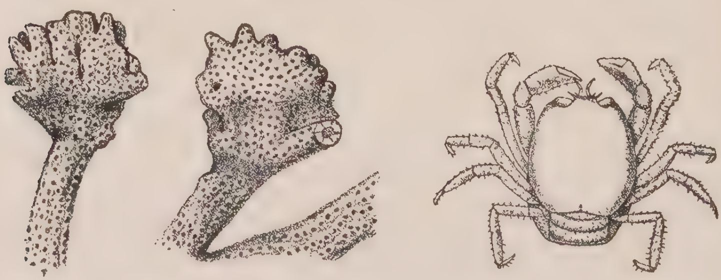


FIG. 130.—Two branches of a coral (Seriatopora) showing galls and inhabited by the crab *Hapalocarcinus marsupialis*. On the right the female crab, extracted from the gall and further enlarged.—After Calman.

a kind of gall with tiny openings through which streams in and out the water which she breathes, and which brings the minute organisms upon which she feeds. Her body is heavy and clumsy,

and has the appearance of that of a parasite, and her mouth-parts are adapted to the nature of her food. Lastly, the cases of certain barnacles may be cited. As is well known, the common Acorn Barnacles of the genus *Balanus* are sessile on rocks, etc., though they may often be found on the backs of crabs. Another genus, *Conchoderma*, is found on inanimate floating objects, but more often on whales. *Coronula*, on the other hand, is never found except on whales, and its shell is elaborately folded so as to form a number of chambers into which prolongations of the whale's epidermis grow, and thus securely fix the shell. *Tubicinella* is yet more firmly lodged, for its shell is sunk in the whale's skin with only

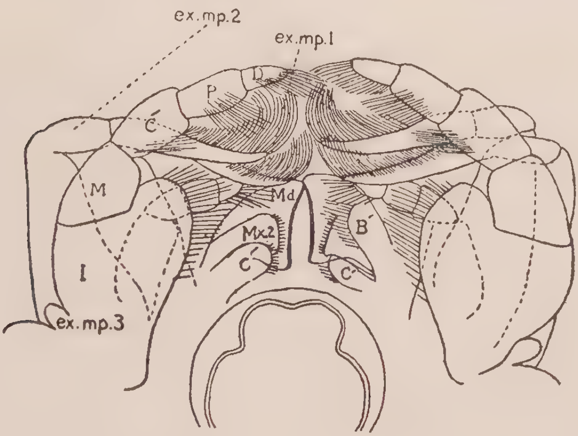


FIG. 131.—The mouth-parts of *Hapalocarcinus*, showing the fringes by which the food is gathered from the water.—From Potts.

B., Basipodite; *c.*, coxopodite, of first maxilliped; *ex.mp.*, exopodites of maxillipides; *Md.*, mandible; *Mx.*, maxilla.

the opening exposed. The chief advantage that the barnacles gain is probably the increased food supply made available by the whale's movements through the water. In so far as any of them may discommode its host, it must be considered a parasite. By the stalked barnacle *Anelasma* the boundary between synœcy and parasitism is definitely overstepped, for in it the mouth parts and limbs are reduced and the animal, with its stalk embedded in the flesh of a shark, absorbs nourishment from its host by roots. With the harmless but one-sided relations that exist between living animals, we may class those cases in which an animal avails itself, for shelter only, of part of the dead body of another, as when a hermit crab lives in the shell of a whelk, or a protozoan makes from the spicules

of a sponge a covering for its own body; and those in which an animal shelters in the empty burrow of another.

(iii) To the third class of relations of assistance between animals we may give the name of *Servitude*. In that it is detrimental to one member, it differs but in degree from relations of hostility, and among such it resembles parasitism by involving prolonged association between individuals; but in parasitism the individual which derives benefit resides on or in the body of its host, and usually inflicts more serious damage than is suffered in servitude. Moreover, for some reason that is not clear, the servitude is often not resented or striven against by the injured party. A typical example of this relation is that of the slave-making ants.

FIG. 132.—Barnacles (*Coronula diadema*) on the skin of a whale.—From Calman.

Several warlike species of pale or red ants have the habit of raiding the nests of smaller black or brown ants and carrying off worker pupæ, which are reared in the raiders' nests and give rise to a race of black slaves by whom a part or all of the work of the nest is performed. The Warrior Ant of Britain (*Formica sanguinea*), a courageous species of much tactical ability, carries off the pupæ of *F. fusca*, the Brown Garden Ant. It is perfectly able to live without the assistance of slaves, and often does so, but it has been observed that in mixed nests the slaves do most of the housework and are more skilful at it than their masters. The Amazon Ant (*Polyergus rufescens*), a continental species, is absolutely dependent upon slaves for its existence, and can hardly even feed itself, so that it is in danger of starvation in the midst of plenty if it have no servants.

But its qualities as a warrior are magnificent. Speaking of them Sharp says: "When an individual is fighting alone its audacity is splendid, and it will yield to no superiority of numbers; when the creatures are acting as part of an army the individual boldness gives place to courage of a more suitable sort, the ants then exhibiting the act of retreating or making flank movements when necessary. This species is provided with mandibles of a peculiar nature; they are not armed with teeth, but are pointed and curved; they are therefore used after the manner of poignards, and when the ant attacks a foe it seizes the head between the points of these curved mandibles and driving them with great force into the brain instantly paralyses the victim. Mandibles of this shape are evidently unfitted for the purposes of general work. . . . The ants that *Polyergus* usually attacks are *Formica fusca*; after it has routed a colony of these, *P. rufescens* pillages the nest and carries off pupæ and some of

Fig. 133.—*A.*, *Bombus terrestris*, a humble bee; *B.*, *Psithyrus vestalis*, its lodger.—After Sladen.

the larger larvæ to its own abode. When the captives thus deported assume the imago state, they are said to commence working just as if they were in their own houses among their brothers and sisters, and they tend their captors as faithfully as if these were their own relations. . . . The servitors are by no means deficient in natural courage, and if the place of their enforced abode should be attacked by other ant enemies they defend it bravely." What is probably an advanced stage of the same habit is found in the remarkable and rare ant *Anergates atratulus* of Central Europe, which has no worker caste but only males and females, both weak and helpless. These are found in small numbers in the nests of the small ant *Tetramorium cæspitum*, tended by workers of the latter although these could easily kill them. How this arrangement is arrived at is unknown, but it seems likely that a female *Anergates* enters a *Tetramorium* nest, where she either finds no queen or kills the queen, and is then accepted by the workers. Here we may class

the habits of the Lodger Bees (*Psithyrus*). These are related to the Humble Bees (*Bombus*), and in appearance mimic them species for species. Each lives in nests of the species which it resembles, and feeds itself and its larvæ on the stores of honey and pollen laid down by the rightful owners of the nest for themselves. Its presence is not useful to the hosts in any way that has been discovered, and it is undoubtedly prejudicial to them by greatly diminishing the size of the family that they can support. Thus Hoffer found that at the end of the summer a mixed nest contained a queen

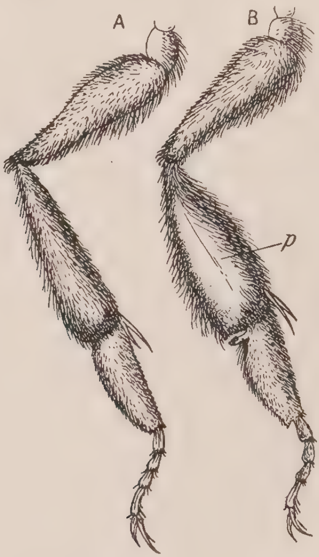


FIG. 134.—The hind leg of *Psithyrus vestalis* (*A.*), and *Bombus terrestris* (*B.*).—After Sladen.

p., The bare patch on the leg of the humble bee, on which pollen is carried. This organ is not possessed by the lodger bee.

Bombus and fifteen workers with fifteen specimens of *Psithyrus*, whereas had it been inhabited only by the humble bees it would have had a population of about two hundred. Yet for some reason the *Bombus* does not resent the presence of its lodgers, and continues to work for their support. When a female lodger bee was introduced to a nest which did not contain one, its arrival caused a hubbub of curiosity, but it was accepted without being attacked. Interestingly enough, a similar attempt to introduce a lodger to a nest which already contained one was defeated by the intruder in possession driving away the newcomer. The industrious and thrifty habits

of the Hymenoptera make them peculiarly liable to be victimized in this way. Many other animals avail themselves or their larvæ of the food or shelter provided by the labours of ants and bees. Curiously enough the profiteers are often themselves bees or ants, though the same habit is found in various other creatures, as in the Death's-head Moth, which steals honey from hives. Here also may be classed the well-known habit of the cuckoo, and the cases in which birds drive others from their nests and take them for their own occupation; though this might also be regarded as a relation

Fig. 135.—*Melia tessellata*, bearing in its claws two sea-anemones.

of hostility. A marine example of animal servitude is afforded by the little crab *Melia*, which is an inhabitant of coral reefs, but not confined in its wanderings to the branches of living corals, and makes use of the stinging powers of a zoophyte in a different way from those of the synœcious forms we have already described. In each of its pincers, the fingers of which are provided with sharp teeth so as to give it a hold of the soft body of the polyp, it grasps a small anemone which it has sought for and picked up. The tentacles of the anemones are turned outwards, and the crab uses them for defence and for feeding. If it be assailed it thrusts the polyps towards the enemy, warding him off with their stinging tentacles.

If they capture food, the crab with one of its legs rakes the morsel from their grasp and places it in its own mouth.

The several classes into which we have divided associations of animals for the purpose of describing more easily the immense variety of them that exists, are, as will partly be realized from what has already been said, not at all sharply divided. Probably the best instance of a series of them, passing from mutual assistance of the most marked kind to positive parasitism, is afforded by the very large and varied fauna of "inquilines," as they are called in entomology, which is found in the nests of ants, where there is obtainable not only shelter and relative immunity from attack on account of the defence which these courageous insects put up with stings and mandibles, but also food gathered by their unceasing exertions. Intrusive species of ants, plant-lice, bugs, orthoptera, thysanura, and Poduridæ, butterfly larvæ, spiders, mites, and woodlice are found in the nests, but perhaps the most common guests are beetles. Not only the aphid bugs already mentioned, but various other species (especially of various families of beetles, such as certain Pselaphidæ and Staphylinidæ) provide secretions which the ants devour. Others live in synœcy, tolerated by the ants, to whom they do no service. To others the ants are hostile, but they are able to defend themselves and to avail themselves of the services of their hosts. Others are actually parasitic upon the bodies of the ants.

A survey of the relations of animal species to one another shows above everything else that none of them is carrying on a solitary traffic with its lifeless surroundings. Everywhere the local assemblage of animals is no collection of independent units, but a complex system of beings in constant interaction with one another and with their vegetable and inorganic environment. Between them they have established an equilibrium that is upset by the removal of any of their company or the introduction of a stranger, whether this happen by a change in their surroundings or by the agency of man. The infinite intricacy of such systems is as yet little unravelled by science. Only here and there do we get a glimpse of one of the threads of their complex entanglement. The example cited by Darwin is well known. Clover is fertilized by humble bees; the nests of humble bees are destroyed by mice; mice are kept down by cats. Hence a connection between the number of cats in a village and the fertility of the clover in its fields. Again, it is said that the growth of the taste for conger in London so stimulated the fishery for it that its numbers were reduced in places on the coast; octopus, upon which the conger fed, increased; and this in

turn brought about a decrease in the number of lobsters and crabs, which are the prey of the octopus. The danger of introducing new animals to the fauna of a country is well known. The Rabbit in Australia and the Gipsy Moth (*Liparis dispar*) in America, freed in their new habitat from their natural enemies, are familiar examples. Both for fisheries and for economic entomology the study of this branch of zoology is of the highest importance.

CHAPTER V

RELATIONS BETWEEN ANIMALS OF THE SAME SPECIES

BETWEEN members of the same species, normal relations of *hostility* are naturally rare, since a species which directed any considerable part of its energy to destroying its own members would in most circumstances soon become extinct. Such relations are avoided either by an instinctive tolerance or by the establishment of separate "beats" such as many solitary animals possess. Nevertheless they exist normally to a limited extent in some cases, and may arise abnormally in others. (i) The adults of a good many carnivorous and omnivorous animals, especially where there is no care of the brood, or where the male associates with the female only for the purpose of impregnation, are liable to devour the young. This happens, for instance, with many fishes; and Sinclair describes it in the centipede *Lithobius*, where if a male sees the female carrying a newly-laid egg in the little pair of hooks which she possesses for the purpose, "he makes a rush at the female, seizes the egg and at once devours it." All the proceedings of the female after laying an egg "seem to be directed to the frustration of this act of cannibalism. As soon as the egg is firmly clasped in the little hooks she rushes off to a convenient place away from the male and uses her hooks to roll the egg round and round until it is completely covered by earth, which sticks to it owing to the viscous material with which it is coated; she also employs her hind legs, which have glands on the thighs, to effect her purpose. When the operation is complete the egg resembles a small round ball of mud, and is indistinguishable from the surrounding soil. It is thus safe from the voracious appetite of the male, and she leaves it to its fate." The male of the Mole Cricket (*Gryllotalpa*) is also given to devouring the young, which are guarded by the mother in the burrow which she makes for them. (ii) Conflicts arise when the boundary of a beat is transgressed, as, for instance, among robins when the young come to their powers and enter into competition with their elders. (iii) In many species the males fight

among themselves for the possession of the females. (iv) In a few cases, as among spiders and bees, the females kill the males. (v) The members of a herd or pack will often destroy, and sometimes afterwards devour, one of their number which is wounded or falls sick. This has been supposed to be due to an instinct by which the sight or the sound of the voice of a wounded fellow excites rage, which is expended upon an enemy if one be visible, but if no such object present itself, is blindly vented upon the unfortunate comrade. (vi) Not infrequently, at least among domestic animals, a mother will destroy her young, especially if she be interfered with while she has them in charge. This is doubtless due to a misdirection of some instinct. Among fowls it is perhaps caused by the movements of the chick being mistaken for those of some enemy attacking the eggs. The egg-eating habit acquired by some hens may arise as a perversion of the custom of cleaning the nest by eating eggs that are accidentally broken.

Relations of *competition* between animals of the same species are practically universal. Where, by the establishment of organized communities, they are avoided between individuals, they exist between the communities. They can only be suspended for a time when, by migration into a new or favourable district or by the sudden increase, absolute or relative, of some other species of organism, food becomes for a while plentiful enough for all. Like the similar relations between members of different species, they may easily lead to active hostility.

Relations of *assistance* between members of the same species fall into three classes—those of societies, of parents and young, and of the sexes. Not all assemblages of members of a species are *social*. Many are due merely to relationship, as the "nests" of caterpillars, or to the attraction of food or shelter. Others, starting perhaps from these, have in them the beginnings of social organization in that they benefit their members by mutual watchfulness and defence, as in herds of wild cattle, or by assistance in hunting, as in wolf-packs. Even when no regular association can be said to exist, the cry of an animal in pain is a warning of danger to other members of its species in the neighbourhood. Other associations serve the construction of common habitations, such as beaver ponds and the communal nests of certain birds. Others, finally, by division of labour, increase the efficiency of all their members as a true society. These occur only among ants, bees, wasps, and white ants, and in mankind. In Man the division of labour is brought about by intelligent arrangement, and by differences of aptitude between the sexes and between individuals, which are perhaps

of greater value to the species than is commonly recognized. In insects division of labour is due to the existence of castes, specialized in bodily structure and in instincts. In social wasps and bees

FIG. 136.—Castes of the Honey Bee.

A., Male or drone ; *B.*, female or queen ; *C.*, sterile female or worker.

there are usually only three varieties of individual—males, females or "queens," and unfertile females—but sometimes in humble

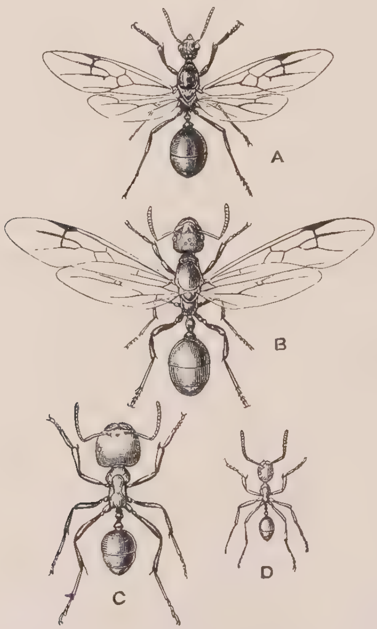


FIG. 137.—The castes of the ant *Aphænogaster barbarus* of Algeria.—From Sharp.

A., Male ; *B.*, winged female ; *C.*, large worker or soldier ; *D.*, small worker.

bees a caste of small fertile females may occur. In ants the number of castes is often greater. There are known among these creatures winged and wingless males, winged and wingless females, intermedi-

ates between females and workers, soldiers, " major workers," and several kinds of " minor workers." These are never all present in the nest of any species, but as many as half a dozen of them may be found. Among white ants there are, besides males and females

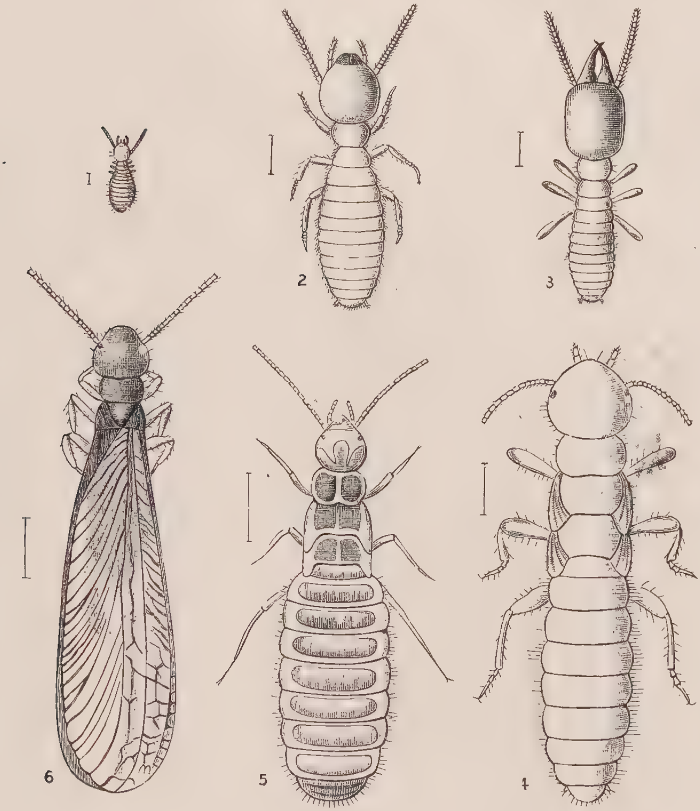


FIG. 138.—Some forms of the white ant *Termes lucifugus*.—From Sharp.

1, Young larva; 2, adult worker; 3, soldier; 4, young complementary queen; 5, older substitution queen; 6, perfect winged insect.

(" kings " and " queens "), " soldiers " and workers of both sexes, and several kinds of " reserve royalties."

The possibility of relations *between parents and young* arises as soon as an egg or bud, by fission, ceases to be a part of the body of its parent and assumes an individuality of its own. It is then at the most helpless stage of its life. Sometimes the young are from the first in no way protected or provided for by the

parents,[1] but are cast naked into the world, to perish or survive as may happen, the ova being even set free unfertilized. Naturally this complete neglect is not found in land animals, for in the air reproductive bodies whose protoplasm was naked could not live or travel. It is practised especially among the Protozoa, Sponges, Cœlenterates, Echinoderms, and Fishes. When it occurs there is a very large production of young, so that some of them may outlast the helpless period. Broadly speaking, it is true that the better the young are protected and provided for the smaller is their number.

Total neglect of the young, however, is comparatively rare among

FIG. 139.—Frog spawn.—(Photo by W. B. Johnson.)

animals. By most parents there is given to their offspring in the early stages some sort of protection from enemies and from such hardships as drought; often they receive also nutriment; provision is generally made for the fertilization of ova; and sometimes there is maintained a suitable temperature for their development. (*a*) (i) *Provision for eggs* may merely consist in the sheltering of free-lying ova within the body or habitation of the mother until they are fertilized—which in this case is accomplished by sperma-

[1] Membranes secreted by the egg itself are, of course, outside the category of protective structures provided by the parent.

tozoa drawn to them by currents set up by the mother—as in sundry cœlenterates, molluscs, tunicates, etc.; or till segmentation has begun, as in other members of these groups. (ii) Most eggs are fertilized, either by sexual congress or without it, before they are laid. Others are not, and there is then sometimes no special provision for their fertilization; but many fishes and frogs and some other animals, by coming together at the time of laying, provide for the fertilization of the spawn outside the body of the mother. (iii) When ova, unsegmented or segmented, or asexual reproductive bodies, are set free, they are usually protected by some kind of shell, or by a layer of slime or jelly secreted by the mother. If the case of an unfertilized egg be tough, or thick, like that of the sea-urchin *Strongylocentrotus* which is shown in Fig. 140, it has a little opening, the "micropyle," for the entrance of the spermatozoon. (iv) Sometimes, as in earthworms and spiders, a number of eggs are enclosed in a cocoon which the mother secretes or spins. (v) Frequently the eggs are laid in places which are suitable for them on account either of shelter or of the neighbourhood of food. Thus snails, grasshoppers, and many other animals bury their eggs in the ground, the Grass Snake will choose a manure heap or some other warm spot, various insects the food-plants of their larvæ, and ichneumon flies the bodies of the larvæ of other insects within which their own are parasitic. Sometimes more elaborate arrangements are made. The Burying Beetle (*Necrophorus*, Fig. 5) lays her eggs in the dead bodies of small animals, which she finds and inters, so that the larvæ have both food and shelter. The Dung Beetles (*Scarabæus*, etc., Fig. 10) place in a chamber in the soil balls of manure, more carefully made than those which serve the adults for food, and in these deposit their eggs. Certain solitary wasps[1] construct underground galleries with chambers, place in them the bodies of insects which they have numbed, but not killed, by stinging them in ganglia of the nerve cord, and lay their eggs upon the helpless victims, which serve the larvæ for food. An equally remarkable egg-laying is that of the little Central European fish known as the Bitterling (*Rhodeus amarus*), which avails itself of the well-known habit of the Freshwater Mussels (*Anodonta* and *Unio*)

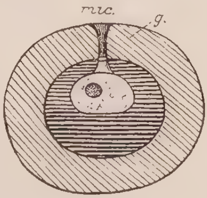


FIG. 140.—A diagram of the structure of the egg of *Strongylocentrotus lividus*, a sea-urchin. The ovum with its nucleus is seen enclosed in a gelatinous covering (*g.*), through which leads the micropyle (*mic.*).

[1] *Sphex*, *Cerceris*, etc.

of liberating their larvæ when fishes pass above them, in order that the larvæ may cling to the fishes and undergo their metamorphosis

FIG. 141. The Edible Snail (*Helix pomatia*) laying its eggs.—After Meisenheimer.

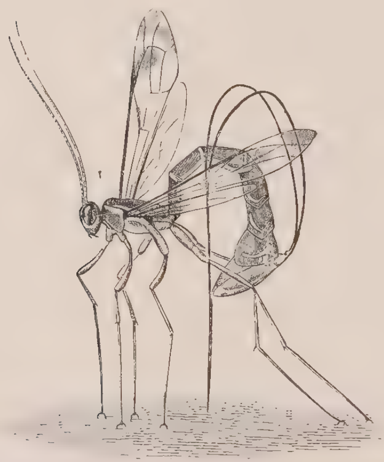


FIG. 142.—The ichneumon fly *Thalessa lunator*, piercing the bark of a tree with her ovipositor in order to reach a wood-boring larva.—From Sharp, after Riley.

as temporary parasites in the skin of their hosts (Fig. 419). The breeding season of the Bitterling coincides with that of the mussels, and at this time the female fish acquires a long ovipositor. This it

inserts between the gaping valves of the molluscs and lays its eggs upon their gills. There, after being fertilized, they develop, leaving their host about a month later, when they are some 10 mm. long. This curious habit of reciprocal parasitism might almost be classed with cases of mutualism, though there is no sign of accommodation of either partner to the benefit of the other. (vi) Frequently the eggs are fastened, either separately or by a common covering, to the spot upon which they are laid. The glueing down of the eggs of many insects and molluscs, and the anchoring of the spider's cocoon, are well known.

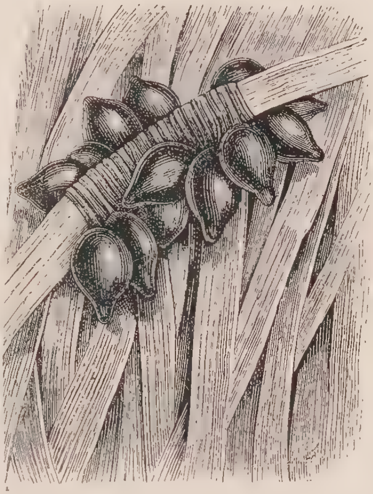


Fig. 142*a*.—Eggs of the Squid (*Sepia*), laid upon sea grass.

(*b*) Once laid, eggs are usually abandoned, but sometimes one or both *parents remain with them* to protect them, and occasionally also to hatch them by the warmth of their bodies. This care of the eggs is, of course, the rule with birds, among which certain cuckoos and cow birds alone quite abandon their young. In other

Fig. 143.—The Butterfish (*Pholis gunnellus*) coiling around its eggs.—From Bridge, after Holt.

groups of animals it occurs sporadically.[1] The Octopus is said to brood over her eggs, renewing the water around them by her

[1] In social insects the eggs are regularly sheltered and cared for; but this is done for the most part by the community, and only sometimes and for a short while by the mother.

9

siphon. The Earwig, the Mole Cricket, and some other insects guard their eggs. The Butterfish (*Pholis gunnellus*) rolls its eggs into a ball and remains coiled about them. The male Lumpsucker

FIG. 144.—The nest of the Fifteen-spined Stickleback (*Gasterosteus spinachia*). —From Furneaux.

(*Cyclopterus*) tends the spawn for weeks. The males of the Sticklebacks (*Gasterosteidæ*) build a nest of pieces of weed glued together by

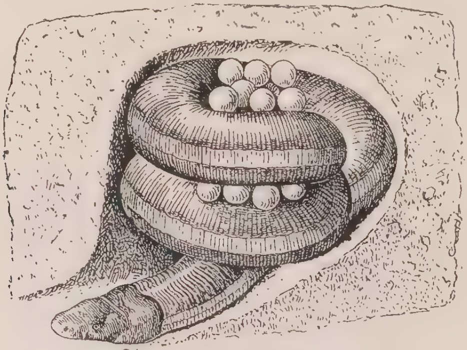


FIG. 145.—*Ichthyophis*, one of the Gymnophiona, in its burrow with its eggs.—After Sarasin.

a secretion which is temporarily provided by the kidneys. In this the female lays her eggs, and after the fry are hatched the father protects them till they are able to take care of themselves. Various

other fishes have similar habits. The female of the Gymnophiona (Amphibians) lives coiled around her eggs in a burrow until they hatch. Some newts behave in the same way. The female Python protects her eggs by coiling round them, and at this time her temperature rises several degrees, probably to promote hatching.

Eggs which are thus cared for by their parents are usually placed in some kind of nest. The nesting habits of birds are exceedingly varied. The simplest nests serve merely to keep the eggs together while they are being hatched, or to hold them and the young out of harm's way; but those that are more elaborate give

Fig. 146.—Ringdoves and their nest.

protection against cold, wet, and sometimes the attacks of enemies. Only a very few birds make no nest of any kind. Some penguins (Fig. 159) carry their eggs and young upon their feet, which shield them from cold beneath. Some auks lay a solitary egg upon the bare rock, and those of the Nightjar are placed upon the soil. Ostriches drop their eggs into a hole scraped in the desert sand, and there the male incubates at night those of a band of females, leaving them in the daytime to the warmth of the sun's rays. Some megapodes also bury their eggs in sand; others raise a hot-bed of dead leaves for them, but take no further care of them. Many gulls, sandpipers, and plovers make a shallow pit in the soil or shingle. The grebes and some rails heap upon growing water-

Fig. 147.—A linnet's nest, drawn from nature by the late Mrs. A. G. Muirhead.

Fig. 148.—A wren's nest, drawn from nature by the late Mrs. A. G. Muirhead.

weed in the places they frequent a rude, half-floating mass of portions of the plants, whose heat, as it decays, helps to hatch the eggs laid upon it. Flamingoes, living also in marshy spots, erect piles of mud with a hollow on the top for the eggs. Nesting in burrows

FIG. 149.—The hanging nest of the Weaver Bird cut open.—From *Cassell's Natural History.*

is not uncommon. The Kingfisher has this habit, and makes a bed for her eggs from the undigested fish bones which she casts up. The Sand Martin is among the birds which bore holes in soft cliffs : she lays her eggs upon feathers. Woodpeckers bore into trees. Swallows and House Martins build nests of pellets of clay, and the Oven Birds of South America construct of mud, upon the roots of

mangroves or the boughs of trees, the globular "ovens" in which their eggs are laid. The commonest nesting habit is that of building in trees and shrubs with twigs and other parts of plants. Pigeons make a mere platform of sticks. The great Passerine group, which comprises more than half the known species of birds, have usually the same habit more highly developed. From various materials, not only vegetable but often also animal, such as hairs and feathers,

FIG. 150.—The Tailor Bird (*Orthotomus longicaudus*) and its nest.

they weave, each with its own degree of skill, nests of a great variety of shapes—open or covered, and sometimes hanging from a bough. Often they use saliva to soften or glue together their building materials. Swifts make a greater use of saliva as cement, and certain of them build of it alone the nests that are sought after by Chinese epicures. The Tailor Bird spins a thread of cotton and sews together the edges of a leaf or pair of leaves around its nest, fastening the thread with a knot at the end. Many birds, such as seafowl, herons, and rooks, breed in flocks; others, like the

Sociable Grosbeak of South Africa, build communal nests, which may contain two hundred or more separate domiciles. Various fishes, as the Stickleback already mentioned, build nests which serve the same purpose as those of birds. Some mammals, as mice (Fig. 14), squirrels, and moles, make them for the shelter of the young after birth. Most of the dwellings of insects which are known as nests are communal houses for individuals of all ages,

FIG. 151.—Nests of the Sociable Grosbeak.

but the Mole Cricket (*Gryllotalpa*) and some of the other species which watch over their young do so in shelters which they construct for them.

A larger number of animals protect their eggs by carrying them upon the body, or retaining them in the habitation of the parent, until they hatch. This habit is especially characteristic of the Crustacea, which, with a very few exceptions (some ostracods, some copepods, penaeid prawns) all possess it. It is common

among frogs and toads. Other well-known animals which practise it are the Freshwater Mussels (except *Dreissensia*) and the Sea Horse (*Hippocampus*). Its details vary greatly from case to case. Sometimes the young hatch in a larval stage, as those of crabs, copepods, barnacles, freshwater mussels, etc.; sometimes they have nearly the adult form, as in amphipod and isopod crustaceans and the Crayfishes; and in this case they may be set free at once on hatching, or may remain clinging to or crawling upon the body of

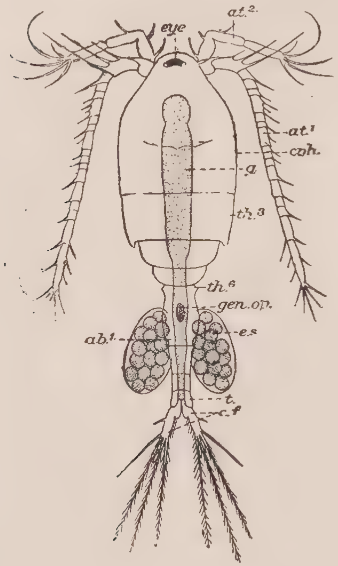


FIG. 152.—A female *Cyclops* carrying eggs.

*ab.*1, First abdominal segment; *at.*1, antennule; *at.*2, antenna; *c.f.*, caudal fork; *cph.*, cephalothorax (fused head and first two thoracic segments); *e.s.*, egg sac; *eye* (single and median); *g.*, alimentary canal; *gen.op.*, genital opening; *t.*, telson; *th.*3, *th.*6, third and sixth thoracic segments.

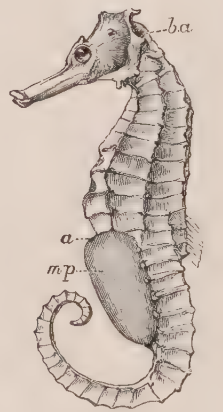


FIG. 153.—The Sea Horse (*Hippocampus*).—From Boulenger.

a., Anus; *ba.*, gill opening; *mp.*, brood-pouch.

the mother for some time. Eggs may be merely retained in the burrow of the parent, as by stomatopod crustaceans and some polychæte worms; or may be carried in masses hanging upon the body, as in copepods and the Midwife Toad; or cemented to the appendages, as in the decapod crustaceans; or held in an ordinary mantle cavity or similar space, as in barnacles, tunicates, and fresh-water mussels; or in a special brood-pouch, such as those formed by the carapace of cladocera, the structures known as oöstegites upon the thoracic appendages of amphipods, isopods,

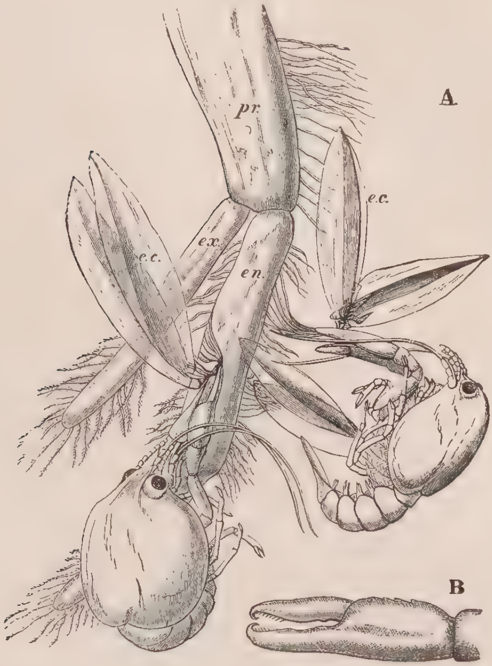


Fig. 154.—*A.*, Two recently hatched crayfish holding on to one of the swimmerets of the mother; *B.*, pincers of such crayfish more highly magnified.—From Huxley.

e.c., Ruptured egg cases; *en.*, endopodite; *ex.*, exopodite; *pr.*, protopodite.

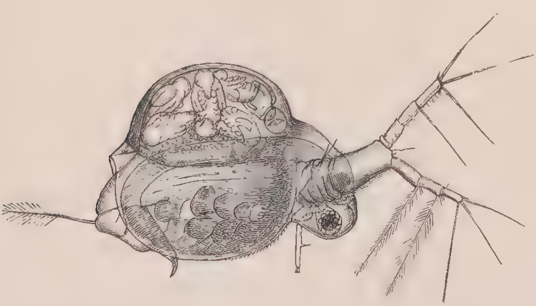


Fig. 155.—*Monia rectirostris* with developing eggs in the brood-pouch formed by the dorsal part of the carapace.—From the *Cambridge Natural History.*

mysids (Fig. 285), and other crustaceans, folds of skin under the tail of the Sea Horse, the deep grooves (" petals ") upon the back of the sea-urchin *Hemiaster*, etc. The Wolf-Spiders (*Lycosidæ*) carry the egg-cocoon about with them, fastened to the abdomen or held by the jaws, and the young, when they escape from it, ride for a time upon their mother's back. The Frogs and Toads (*Anura*), which are animals adapted to live upon land, with succulent and defenceless larvæ normally adapted to live in water, illustrate admirably the variety of the devices which enable parents to carry their young. In the Midwife Toad of Europe the eggs are laid in long strings twisted into a gelatinous mass, through which the

FIG. 156.—A male of the Midwife Toad (*Alytes obstetricans*) bearing the eggs.—From *Cassell's Natural History*.

father thrusts his legs. From time to time he moistens them, and when they are ready to hatch he enters the water. The male of a Chilian toad (*Rhinoderma*) carries the eggs and young in the croaking sac, which enlarges for the purpose, until they have reached the adult form. In the Surinam Toad the male spreads the eggs over the back of the female, where a little lidded pouch arises for each of them, and in this it develops to the adult form. In a tree-frog of Ceylon (*Rhacophorus reticulatus*) the female places the eggs on her belly, where similar pits arise for them. In the Brazilian Tree-Frog (*Hyla goeldi*) the eggs are borne on the back upon an area surrounded by a fold of skin. These also reach the adult form before they leave the parent. Another South American genus

of tree-frogs (*Nototrema*) has a permanent pouch on the back. Finally, we may place here the remarkable habit of certain penguins mentioned above, which protect their eggs and young from the cold

FIG. 157.—A female of the Surinam Toad (*Pipa americana*), with the young on her back.—From Parker and Haswell.

of their habitat by carrying them on the feet, covered by a fold of skin which hangs over them from the belly.

Other animals retain the eggs within the body [1] till the young reach the larval or adult form, so that when they are set free they

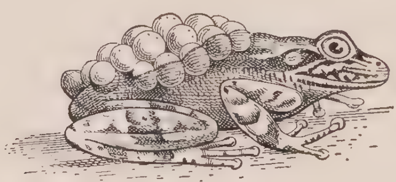


FIG. 158.—A female of *Hyla goeldi* bearing eggs.—From Gadow.

are able to lead an active life. Such animals are said to be *viviparous*. They are less numerous than those which carry their eggs externally, but they occur in many different classes. Here it is only possible briefly to mention a few of them. In many cœlenterates, planula larvæ are formed in the enteron and leave through

[1] This habit is to be distinguished from that of carrying eggs or young in an external brood-pouch, or taking them up again into the mouth.

the mouth, and in some anemones (*Sagartia*, etc.) they are retained till one or more circlets of tentacles have been formed. Many nematode worms are viviparous. The Guinea Worm (*Dracunculus medinensis*), the *Filariæ*, and *Trichinella*, the cause of trichinosis, are examples of this. Viviparity is found in some species of *Peripatus* and in members of various orders of insects, as in *Aphis*, in scorpions, and in some brittle-stars. It appears in fishes, newts,

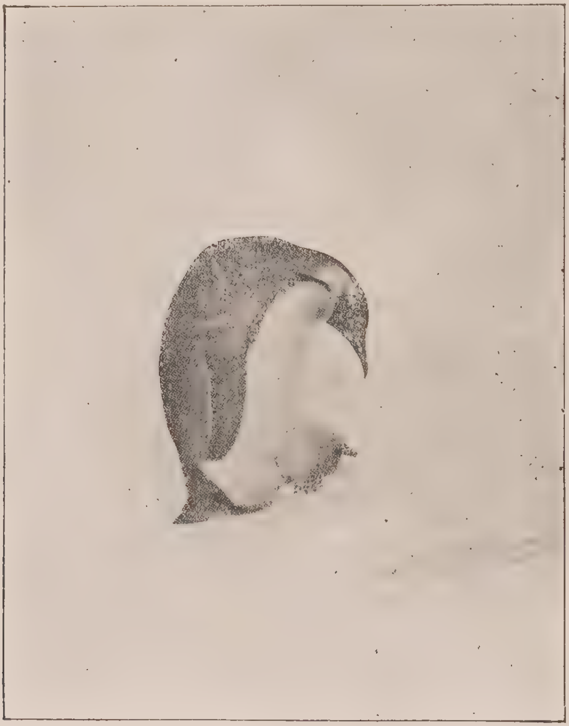


FIG. 159.—An Emperor Penguin nursing its young.—From Wilson.

lizards, and, of course, in mammalia, in which it reaches its highest development. It is of very various grades, from "ovoviviparity," in which the egg has a perfect shell as if it were to be laid, but hatches within the mother's body, as in the Common Lizard (*Lacerta vivipara*), to cases in which, as in mammals, the whole course of development is profoundly modified by it. It may occur in animals which are closely related to others which are oviparous, as, for instance, among the species of *Peripatus* and the Salamanders.

We have already noted that many of those oviparous animals which care for their eggs also protect the young for some time after they are hatched. Many which carry the eggs continue, as we have seen, to bear the young till these can fend for themselves. Those which guard without carrying the eggs may also guard the young, as do the Sticklebacks and, of course, birds, which not only protect and feed their offspring after hatching, but even educate them. Among viviparous animals, mammals are as careful of their young as birds, and some (the Marsupials) are even provided with a pouch under the belly in which they carry the

FIG. 160.—The Antarctic heart-urchin *Hemiaster philippi* bearing its young in the sunken grooves ("petals") on its back.—From MacBride, after Wyville Thomson.

young. The young of scorpions are sometimes carried upon the back of their mother.

(c) Further, it must be noted that young animals are brought into the world by their parents at suitable *seasons*. To those which live under conditions that vary little or not at all with the time of year, one month is not more favourable than another for the beginning of life, and under such conditions many species breed all the year round. In the forests of rainy districts in the tropics, where there is little change from season to season, in the great depths of the ocean, where warmth and light do not wax and wane, because the rays of the sun cannot reach there, and in the equable

waters of tropical and sub-tropical seas, there are many species of which breeding individuals may be found at all times of the year. Where, however, seasons differ much, animals are born at the time at which they will thrive best. A definite breeding season is nearly always the time of year at which food for the young will be most plentiful. This again depends directly or indirectly upon vegetation, and thus in the long run upon temperature and often also upon moisture. Accordingly the young are usually born at the beginning of the warm season, though not when a period of drought is about to set in; and many species, especially those which are

FIG. 161.—The wolf-spider *Pardosa* with young on the abdomen. One of the young is represented below.—From Warburton.

parthenogenetic (p. 175), produce broods in quick succession as long as the favourable conditions last. Primarily, perhaps, the connection between a rise of temperature and the onset of breeding is due to that deep-seated influence of temperature upon the processes of life to which we have already alluded (p. 23), but in its details it is clearly adjusted to the needs of the species. Various animals present exceptions to the general rule in that, for reasons of their own, they breed during the cold season. Thus the trout spawns in autumn, and the Emperor Penguin lays in the depth of the Antarctic winter. An animal may have different breeding seasons in different places, as certain sea-urchins, which breed in June in the North Sea, and in May in the Channel, propagate

throughout the year in the Gulf of Naples; and sometimes there are two races of a species which breed in the same place at different times, like the Spring and Autumn Herrings. In viviparous animals with sexual reproduction, impregnation may take place many months before the young are born; and we have seen that species with strong-shelled eggs that pass the first part of their existence quiescent in unfavourable circumstances often pair at the end of the favourable period. Thus the season in which the new brood of a sexual species appears is not always that at which pairing takes place. The breeding of animals is sometimes adjusted to other events than the great seasons of the year. In certain cases it is connected with the tides. *Convoluta roscoffensis* (Fig. 62) lays its eggs at the beginning of each period of spring tides, *C. paradoxa* at the onset of neap tides, and the habitats of the animals are such that in each case this gives the larvæ the longest period of submergence. Various polychæte worms swarm for breeding, or spawn, at tidal periods. The remarkable Palolo worm (*Leodice viridis*) of the South Pacific sends its swarms to the surface of the sea for two days at the third quarter of the October and November moons, with such regularity that the natives, who collect it for food and greatly esteem it as a delicacy, know with certainty the dates on which it will appear. The sea-urchin *Diadema setosum* at Suez discharges its gametes at each full moon, resting in the interval. The reason for this lunar but not tidal periodicity is unknown.

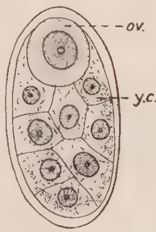


FIG. 162.—The egg of a fluke (*Distomum*), showing yolk cells (*y.c.*) enclosed with the ovum (*ov.*) in the shell.

(*d*) So far we have spoken only of shelter and protection given by parents to offspring. Often they also provide them with *nourishment*. This happens in several ways. (i) The reserve of food which is contained as yolk in the protoplasm of the ovum is its birthright and part of itself, but there is sometimes an additional supply, which is enclosed with the ovum in its shell. Such is the yolk of the eggs of platyhelminthes and the white of that of birds. (ii) Again, young that are long retained in the body of the parent may receive during development supplies from it. The beginnings of this are found in some of the animals which carry their young in brood-chambers. In various cladocera there exist vascular and glandular arrangements for passing nutrient substances into the water in the brood-pouch. In *Rhinoderma* (p. 138) the little frogs adhere by their backs to the vascular wall of the croaking sac, and

receive nutriment thence by diffusion. In the Sea-horse, blood corpuscles are provided in the brood-pouch for the nourishment of the young. In the tunicate *Salpa* the egg cleaves to the wall of the mantle chamber (*atrium*) where it is attached to a vascular "placenta." Of a number of other animals which carry their young in brood-pouches it is known or suspected that the offspring are nourished by the parent. In viviparous animals the same thing happens, but here it is more widespread and may attain a higher development. In *Peripatus capensis*, for instance, in various insects, in most sharks and rays, and in the viviparous bony fishes

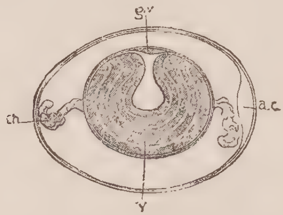


FIG. 163.—A diagram of the structure of the egg of a bird, as seen in a section longitudinal to the egg.

Under the shell, which is porous, are two membranes, which separate at the broad end to enclose an air chamber (*a.c.*), for the use of the chick when its lungs are developed. Within the membranes is the "white," a solution of proteins which serve for the nourishment of the embryo. Twisted cords in the white, known as "chalazæ" (*ch.*), serve to keep the yolk in position and protect it from jolting. All these structures are secreted by the oviduct of the mother. The ovum consists of the large mass of food material known as "yolk," in alternate layers of yellow and whitish substance, and a small amount of protoplasm, most of which is collected in a little patch (*g.v.*) on the upper side. In this patch lies the nucleus.

(various blennies, surf-fishes, the Norwegian *Sebastes*, etc.), a nutritive secretion is provided by the walls of the ovaries or oviducts and is either swallowed or absorbed by the young. In an Indian sting-ray (*Pteroplatea micrura*) the long threads on the wall of the uterus which secrete the nutriment are gathered into two bundles which pass through the spiracles into the pharynx of the embryo. In the Black Salamander only one of the eggs which pass into each uterus develops, the others breaking down to provide food for it. In *Peripatus edwardsi*, in a few sharks (as the "Hounds" of the genus *Mustelus*), in the lizard *Seps*, and in the higher mammalia

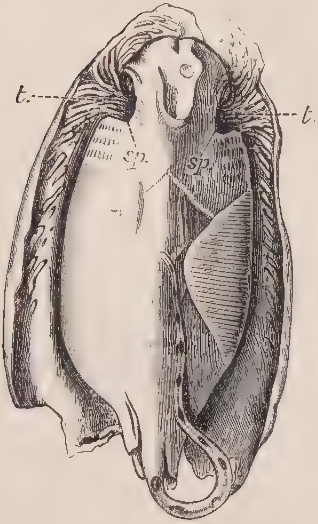


FIG. 164.—The embryo of an Indian sting-ray (*Ptero-platea micrura*), lying in a portion of the uterus, which has been laid open.—From Bridge.

t., *t.*, Two bundles of thread-like processes of the uterine wall, inserted into *sp.*, *sp.*, the spiracles.

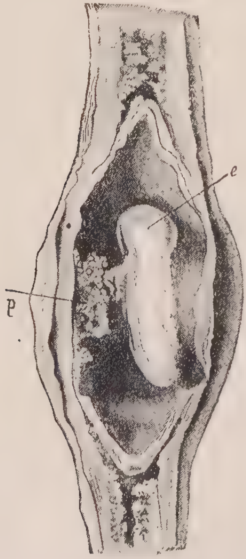


FIG. 165.—Part of a uterus of *Peripatus edwardsi*, opened to show an embryo (*e.*), with its placenta (*p.*).—From Lang, after von Kennel.

(*Eutheria*) there is a *placenta*—a highly vascular structure on the wall of the uterus, in which the blood vessels of mother and young come into intimate contact, and nourishment and the gases of respiration diffuse from the one to the other. (iii) A third mode in which young animals are nourished by their parents is the provision of milk for them after birth. This, of course, is found in all mammals.

Fig. 166.—The Grasshopper Warbler (*Locustella*) feeding its young.—(Photo by Farren.)

Young pigeons are fed by their parents with a creamy fluid known as "pigeon's milk," produced by the breaking down of the epithelium of the crop. (iv) Lastly, there are animals that forage for their young. That this is the habit of birds and mammals is well known. The queen of many bees, wasps, and ants herself feeds and tends the first generation of the nest, and various solitary Hymenoptera store pollen, honey, or animal food in the cells in which they lay the eggs of the young which they will never see.

Certain generalizations concerning the relations of parents and young may be considered at this point. (i) It is true that the dependence of offspring on parents is in a sense parasitism. The expenditure of energy by the elders which it involves is always fruitless for them, though necessary for the race. If in some cases the relation is rather that which we have called servitude than true parasitism, in others it is certainly parasitic. When the young of freshwater mussels become parasitic upon fishes, or those of the Bitterling in the gills of freshwater mussels, or those of one insect upon the larvæ of another, they are behaving towards members of another species as other young animals frequently do towards members of their own—that is, to their parents. (ii) It is true that the number of eggs is in inverse proportion to the amount of protection and nutriment which is afforded to them. (iii) It is true also that the amount of yolk that an egg contains is in inverse proportion to the amount of nourishment that it receives during development from its parent. *Peripatus novæ-zealandiæ* lays large, yolky eggs. *P. capensis* has a smaller, less yolky egg and retains it in the uterus, where it is nourished by a secretion. *P. edwardsi* has a very small egg and nourishes the embryo by a placenta. The Duckmole (*Ornithorhynchus*) and the Spiny Ant-eater (*Echidna*), which constitute the primitive order Monotremata of Mammalia, lay large, yolky eggs. The remainder of the class retain the ova in the uterus and nourish them there, and in these animals they are minute. (iv) On the other hand, eggs which are carried in a brood-pouch until the young reach a late stage of development are larger and more yolky than those which give rise to free-living larvæ capable of feeding for themselves. (v) It is not true, however, as it is sometimes said to be, that the young of higher animals receive from their parents more care than those of lower. The Rabbit is not a higher animal than cattle, though at birth its young are more helpless and receive more care. The Pigeon is not higher than the Common Fowl, nor the viviparous Black Salamander than the spotted species whose eggs are laid in the water, nor a viviparous sea-anemone than an oviparous sea-urchin. The stage at which the young are born is correlated with the habits of the species. Broadly speaking, the stage at which a placental mammal is born depends upon whether or not it is necessary for it to run with its parents from birth, and the same is true of the hatching stage of birds. The Black Salamander is a mountain species for which access to suitable pieces of water is harder than for the spotted kind. In other cases the correlation is more obscure, but we may be sure that it is there.

From what has been said in the foregoing paragraphs about the relations of assistance between parents and offspring it would appear that they are always one-sided. That is almost true. The unrequited sacrifices of parents are a commonplace. But two curious and interesting cases of another kind must be mentioned. The first of them is thus described by Sharp. "*Œcophylla smaragdina*, a common ant in Eastern Asia, forms shelters on the leaves of trees by joining them together. In doing this it makes use of an expedient that would not be believed had it not been testified by several competent and independent witnesses. The perfect ant has no material with which to fasten together the edges of the leaves; its larva, however, possesses glands that secrete a supply of material for it to form a cocoon with, and the ants utilize the larvæ to effect their purpose. Several of them combine to hold the foliage in the desired position, and while they do so, other ants

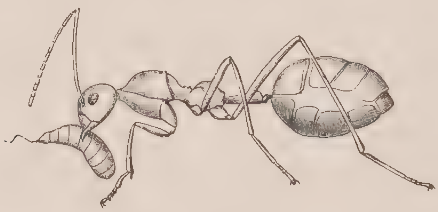


FIG. 167.—A worker of the ant *Œcophylla smaragdina* using a larva to spin a thread.—From Sharp.

come up, each one of which carries a larva in its jaws, applies the mouth of the larva to the parts where the cement is required, and makes it disgorge the sticky material." Here the larva is made to serve the purposes of the community. It may be said to be in servitude. The other case is that of the "pelagic" tunicate *Doliolum*. Here there is an alternation of generations, and the asexual generation reproduces by budding from a stolon which lies on the ventral side of the barrel-shaped body. On the back is a hinder process, the "cadophore," which grows longer as the animal becomes older. From the stolon there break off little segments or "probuds," which crawl by an amœboid ectoderm round the side of the body to the base of the cadophore, and settling upon it become attached to it by adhesion of their ectoderm to that of the mother. Through this, interchange of material can take place between them and her. Those which arrive first attach themselves at the sides of the cadophore, forming two rows of "lateral buds," of which the

youngest are those nearest the base of the process, the elder ones having been carried backwards by its growth. As they become older they develop, and take on something of the organization of the parent, but their digestive system develops at the expense of their other organs, which are degenerate. They are then known as "gastrozooids." Probuds which arrive later have a different fate. They form two rows along the back of the cadophore between rows of gastrozooids; they are known as the "median buds" and later, when they have developed, as "phorozooids." These have much the build of their mother, to whom they are attached

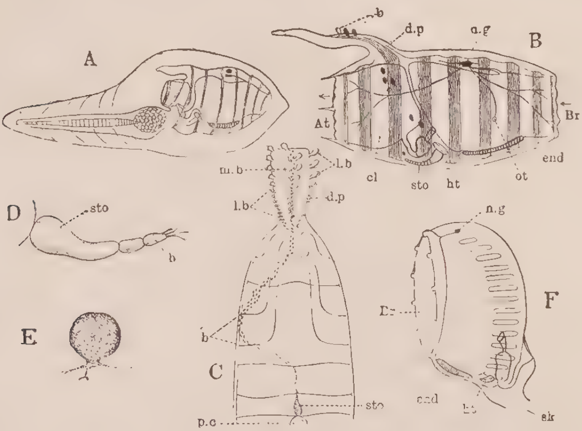


Fig. 168.—The life-history of *Doliolum*.—From Herdman.

A., The tailed larva in its house. This larva grows into *B.*, the asexual individual (oozooid), in which buds are seen beginning the migration from the stolon to the cadophore; *C*, the hinder region of an older oozooid, in which the three rows of buds are established upon the cadophore (cut short); *D.*, the stolon, segmenting; *E.*, a young migrating bud; *F.*, one of the gastrozooids.

At., atrial opening; *b.*, buds; *Br.*, mouth; *cl.*, cloaca; *d.p.*, cadophore; *end.*, endostyle; *ht.*, heart; *l.b.*, lateral buds; *m.b.*, median buds; *n.g.*, nerve ganglion; *ot.*, otocyst; *p.c.*, pericardium; *sk.*, stalk; *sto.*, stolon.

by long stalks. A third set of probuds settles singly upon the stalks of the phorozooids. Meanwhile the mother has lost her alimentary canal by degeneration but continues to tow the whole colony after her upon her cadophore. She is nourished by the food gathered by the gastrozooids. Presently the phorozooids break away and swim free, each trailing behind it the stalk by which it was attached, which has now become very long and bears rows of buds formed by the division of the original probud which settled upon it. Finally, these buds are set free from their nurses and become the sexual generation of the *Doliolum*. In this

remarkable history parent and young form an organized community, working together for their mutual good and for the propagation of the race. Something of this relation exists between social insects, but here the offspring do not undertake their tasks till they are fully adult and they are not exclusively associated with their own parents.

CHAPTER VI

RELATIONS BETWEEN THE SEXES

THE essential relation between the sexes is not one of support afforded by either partner to the other. Only secondarily does it come about that the male protects or provides for the female or, very occasionally, that the female performs such services for the male. Their partnership is primarily one of mutual assistance in a common task. This is not, as might be supposed, the increase of the species by reproduction, which can be more easily effected either asexually in the strict sense or by parthenogenesis, into which sexual reproduc-

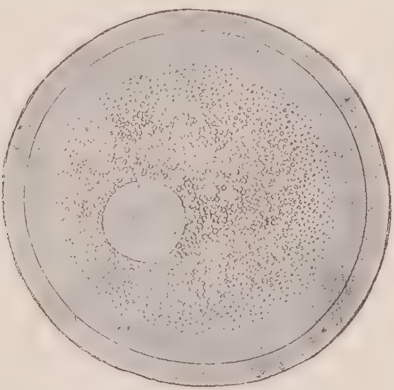


FIG. 169.—A human ovum.

tion often relapses, but the bringing about of conjugation, known in the Metazoa as "fertilization." Conjugation, *in itself*, is not reproduction, but the opposite of that process, since in it the number of individuals is reduced by fusion, as when ovum and spermatozoön unite. In many cases, however, it has come to be part of the proceedings by which animals reproduce their kind. Because conjugation is the fusion of two single nuclei, and the Metazoa have many nuclei, if they are to perform it, they must give rise to uninuclear young (the "gametes" or ovum and spermatozoön); the conjugation must take place

between these; and the body which results from the union of the gametes (the "zygote" or oösperm) must undergo a multiplication of nuclei (segmentation) and a differentiation of cells (development) in order to regain the form of the parent. This process is "sexual reproduction," and the whole machinery of sex exists to bring it about. That this is so proves that it is of immense importance to the organism, though in what its importance consists is, in

FIG. 170.—Human spermatozoa.

spite of a very great deal of speculation and experiment, entirely undecided.

Sex is primarily the differentiation of the individuals of a species into two kinds, adapted to the production of two kinds of gametes; though the differentiation may extend to other functions, such as the part played by the parents in bringing about the union of the gametes, or the nourishment and protection of the young. It is an

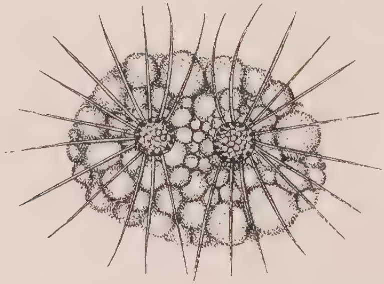


FIG. 171.—The first stage in the conjugation of *Actinophrys sol*.

example of the physiological division of labour between individuals. The basis upon which sex is established is the unlikeness or "dimorphism" of the gametes; and there is found, among the lower animals, a series of grades which lead up to its fully developed form. In such protozoa as *Actinophrys* and *Polytoma* ordinary individuals fuse in conjugation. Here there is not even a difference between gametes and their parents. In others, as in *Polystomella* and similar foraminifera, certain *Chlamydomonas* (Fig. 218), and a number of other mastigophora, the gametes

are little individuals, produced by division of a parent larger than themselves and conjugating while they are small, but all

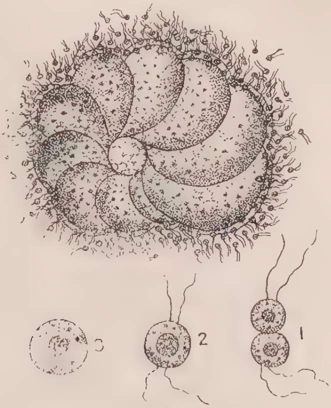


FIG. 172.—The conjugation of *Polystomella*. Above is shown the shell of an individual of the sexually-reproducing (megalospheric) generation, surrounded by the gametes into which its contents have divided. Below, three stages in the union of gametes.

alike. Here there is differentiation between parents and gametes. In others, as in *Pandorina*, *Volvox*, the Malaria Parasite (*Plasmodium*, Fig. 421), and *Paramecium*, there is an unlikeness between the gametes, some being larger than others. The larger kind are known as "female gametes," the smaller as "male

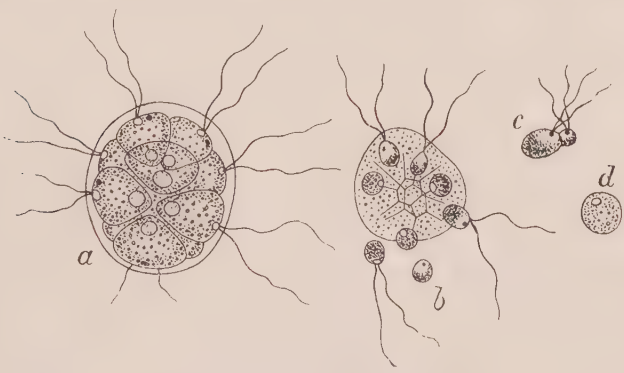


FIG. 173.—*Pandorina morum.*

a., Ordinary colony; *b.*, one individual of such a colony divided into gametes, which are escaping; *c.*, conjugation of two gametes of unequal sizes; *d.*, zygote.

gametes," and in conjugation the pair which fuses consists always of a large and a small member. The unlikeness between them may be only one of size, as in *Pandorina*, or may, as in the others cited, consist also in a difference of form and function like that which exists between ovum and spermatozoön, the one being large and inactive and carrying the bulk of the material for the body of the zygote, and the other small and active, with the function of finding and entering the larger one. Thus division of labour between gametes

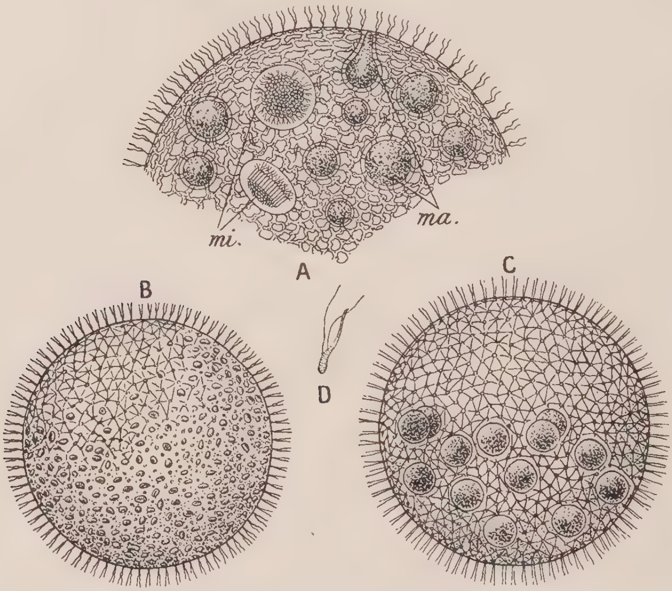


Fig. 174.—*Volvox.*

A., Part of a colony of the hermaphrodite *V. globator*, showing female gametes (*ma.*), and male gametes (*mi.*); *B.*, a male colony of *V. aureus*; *C.*, a female colony of the same species; *D.*, a male gamete of *V. globator*.

has arisen. As regards conjugation these Protozoa are upon the same plane as the Metazoa.

Among organisms upon this plane there exist two modes of parentage of the gametes, the hermaphrodite and the sexual. In *hermaphrodites* both kinds of gamete are formed by one individual: there is here dimorphism of gametes without sex. This is rare among protozoa (*Paramecium* and other ciliates—in which a single micronucleus gives rise to male and female pronuclei—are examples of it, and it is found in some colonies of *Volvox*), but fairly common among metazoa, from *Hydra* upwards, especially among parasitic and other fixed or sluggish animals, in which it is difficult

or impossible for individuals to meet. Hermaphrodites may be self-fertilized, or cross-fertilized, and in the latter case there may be congress of two individuals, as in snails and earthworms, or the spermatozoa may be cast into the surrounding water to find the ova. Sometimes the male organs develop before the female (protandry), so that there is a kind of temporary sex, and then the male stage may

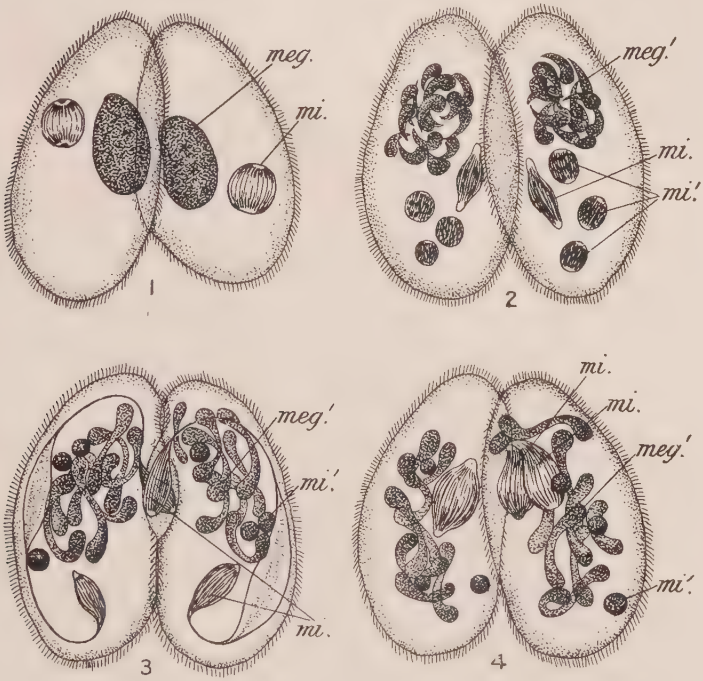


FIG. 175.—Stages in the conjugation of *Paramecium*.—After Doflein.

1, The two conjugants apply themselves by their oval sides; 2, the meganucleus has broken up and the micronucleus has divided into four parts, of which three will degenerate, while the fourth divides again to form the male and female gamete nuclei; 3, the products of division of this nucleus are still connected, but from each conjugant one (the male nucleus) is crossing to the other conjugant; 4, in each conjugant the female nucleus is fusing with the male nucleus which has arrived from the other conjugant, and preparing to divide to form mega- and micro-nuclei for the offspring.

be more active than the female: it is so, for instance, in some parasitic isopoda. Permanent dimorphism is extremely rare in hermaphrodite parents, but it is seen in *Vorticella* and related protozoa, where there are small individuals which seek the large ones, behaving thus like males, and in certain barnacles (*Scalpellum* and *Ibla*). Here small, more or less degenerate individuals live within the mantle of the large normal ones and have lost their

female organs, becoming thus "complemental males." Sometimes the large individuals are without male organs, and thus sexuality is re-established. From the rarity of hermaphroditism among proto-

FIG. 176.—Two individuals of the Edible Snail in sexual congress. —After Meisenheimer.

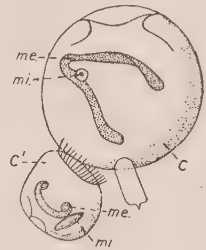


FIG. 178.—Two individuals of *Vorticella*, preparing for conjugation. In the smaller, the micronucleus is in division, the first stage of the formation of gamete nuclei, of which only one will survive.

c., The pseudo-female; *c'.*, the pseudo-male; *me.*, meganucleus; *mi.*, micronucleus.

zoa, and its frequency among animals whose modes of life cannot be primitive, it would seem to have arisen out of the condition in which

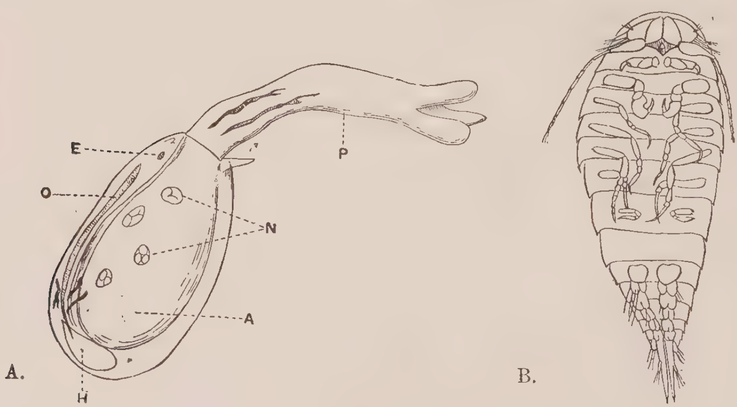


FIG. 177.—The male (*A.*) and female (*B.*) stages of the parasitic isopod *Danalia curvata.*—From the *Cambridge Natural History.*

A., Alimentary canal; *E.*, eye; *H.*, heart; *N.*, phagocytic cells; *O.*, ovary; *P.*, proboscis.

the sexes are separate. By its adoption the advantages which may accrue from division of labour between parents are foregone, except in the cases in which they are reacquired by successional

or permanent dimorphism, but it presents others of its own. For self-fertilized hermaphrodites (which, however, are comparatively rare) the necessity for a coming together of parents does not exist, and in those which are reciprocally cross-fertilized, any meeting between two ripe individuals may bring about fertilization. In these respects hermaphroditism is especially suitable to animals whose habits make pairing difficult. In all cases it distributes the ova among a larger number of members of the species, and

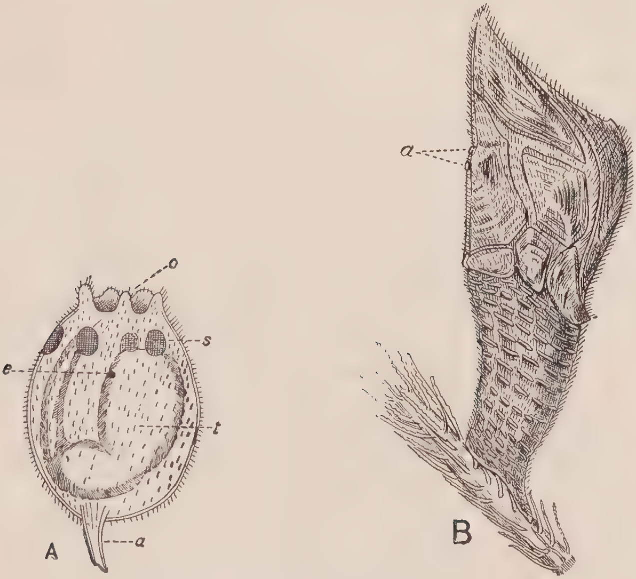


FIG. 179.—A male (*A.*), and a hermaphrodite (*B.*) of *Scalpellum vulgare.*—From the *Cambridge Natural History.*

A., *a.*, Peduncle; *e.*, remains of eye of larva; *o.*, opening of mouth cavity; *s.*, scutum; *t.*, testis. *B.*, *a.*, males lodged on the hermaphrodite.

though perhaps this does not mean that more eggs are produced, it gives a greater chance of survival. The organs of reproduction of a hermaphrodite animal are, naturally, more complicated than those of a related animal whose sexes are separate, and are sometimes extremely intricate. If, as is sometimes assumed, the formation of complex organs puts a strain upon the individual during its development, that disadvantage must attach to hermaphroditism.

In *sexual animals* the two kinds of gametes are formed in separate individuals—males and females. (1) Sometimes, as in most protozoa, cœlenterates, and echinoderms, there is no difference, or

very little, between the sexes save in the kind of gametes that they form. In most of these there is no coming together of male and

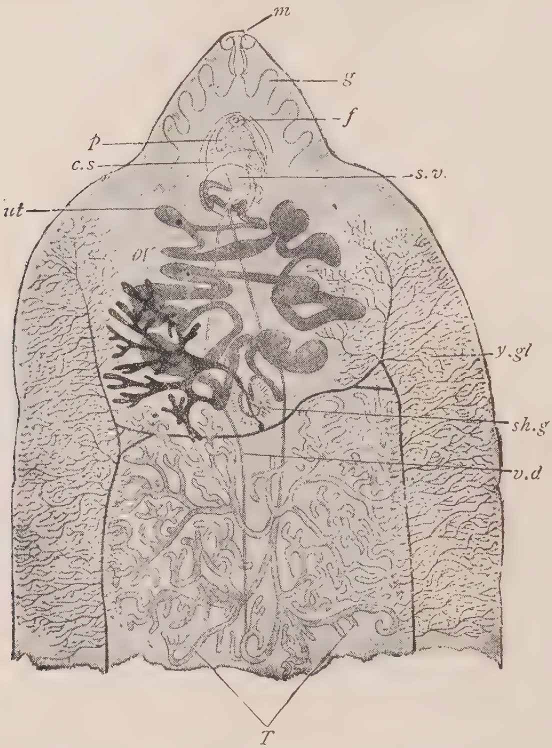


FIG. 180.—The reproductive organs of a liver fluke, from the ventral side.—After Sommer.

cs., Cirrus sac; *f.*, female aperture; *g.*, anterior lobes of gut; *m.*, mouth; *ov.*, ovary (dark); *p.*, penis; *s.v.*, seminal vesicle; *sh.g.*, shell gland; *T.*, testes (anterior); *ut.*, uterus; *v.d.*, vas deferens; *y.gl.*, diffuse yolk glands.

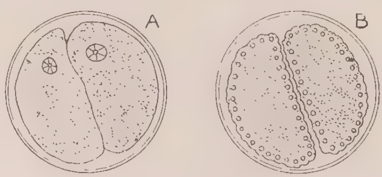


FIG. 181.—Two stages in the gamete formation of *Monocystis*.

A., Two individuals encyst together; *B.*, their nuclei divide and lie at the surface ready to become the nuclei of the gametes.

female for fertilization, but the spermatozoa are cast into the water to drift and swim to the ova, which may also be set free or may await

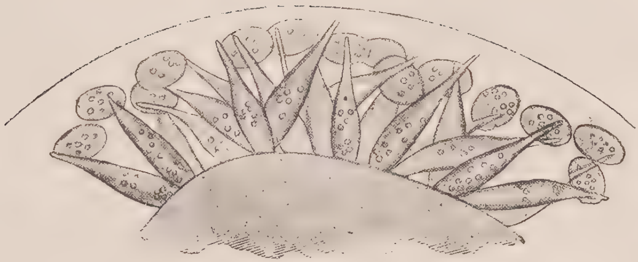


FIG. 182.—Part of a cyst of *Monocystis agilis* showing the two kinds of gametes and the residual protoplasm of one of the parents.—After Hoffmann.

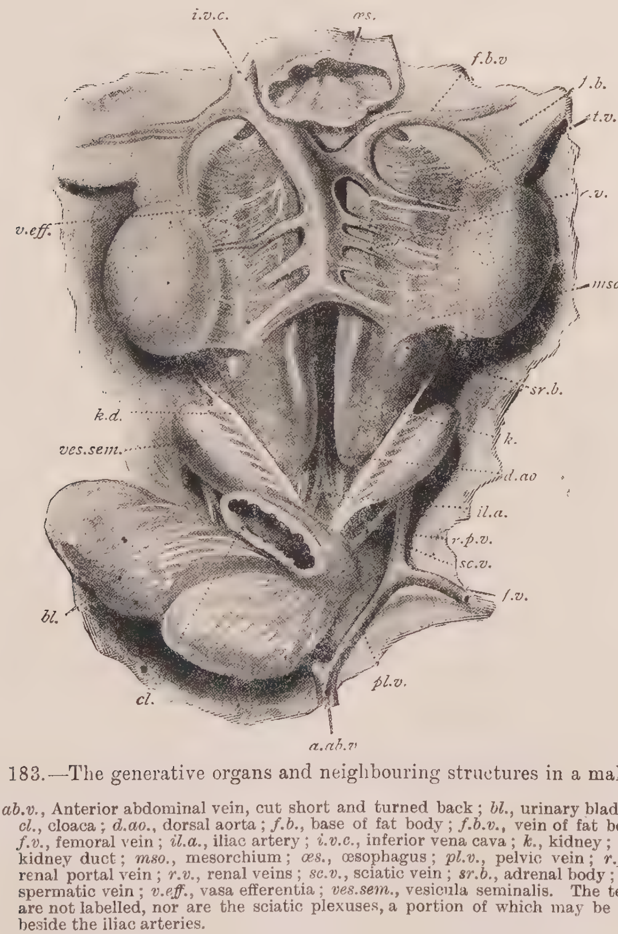


FIG. 183.—The generative organs and neighbouring structures in a male frog.

a.ab.v., Anterior abdominal vein, cut short and turned back; *bl.*, urinary bladder; *cl.*, cloaca; *d.ao.*, dorsal aorta; *f.b.*, base of fat body; *f.b.v.*, vein of fat body; *f.v.*, femoral vein; *il.a.*, iliac artery; *i.v.c.*, inferior vena cava; *k.*, kidney; *k.d.*, kidney duct; *mso.*, mesorchium; *œs.*, œsophagus; *pl.v.*, pelvic vein; *r.p.v.*, renal portal vein; *r.v.*, renal veins; *sc.v.*, sciatic vein; *sr.b.*, adrenal body; *t.v.*, spermatic vein; *v.eff.*, vasa efferentia; *ves.sem.*, vesicula seminalis. The testes are not labelled, nor are the sciatic plexuses, a portion of which may be seen beside the iliac arteries.

the spermatozoa in or upon the body of the mother. Occasionally, however, even at this stage of the differentiation of the sexes, males and females come together to facilitate the fertilization of the ova.

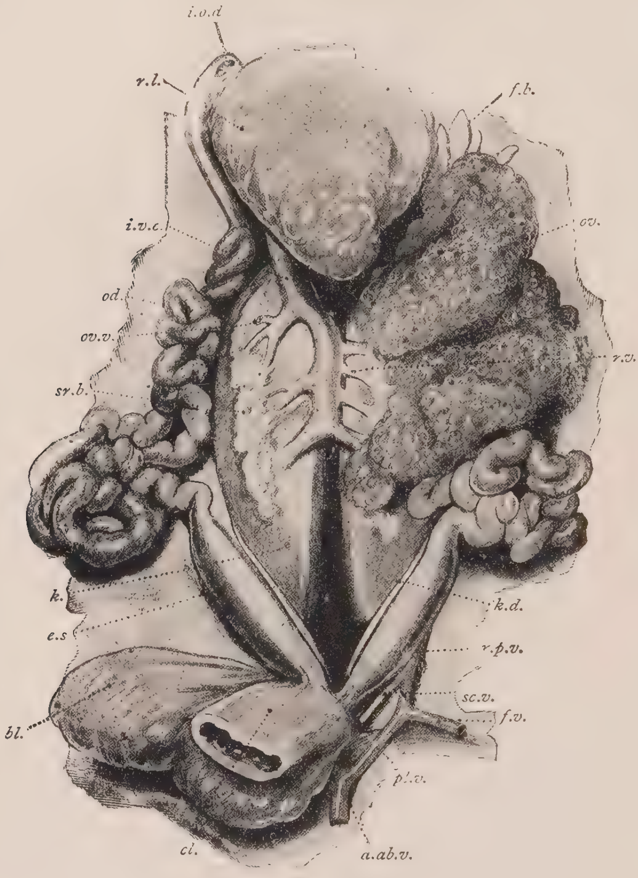


FIG. 184.—The generative organs and neighbouring structures in a female frog.

a.ab.v., Anterior abdominal vein, cut short and turned back; *bl.*, urinary bladder; *cl.*, cloaca; *e.s.*, egg sac; *f.b.*, fat body; *f.v.*, femoral vein; *i.o.d.*, internal opening of oviduct; *i.v.c.*, inferior vena cava; *k.*, kidney; *k.d.*, Wolffian or kidney duct; *od.*, oviduct; *ov.*, left ovary; *ov.v.*, ovarian vein; *pl.v.*, pelvic vein; *r.l.*, right lung; *r.v.*, renal veins; *r.p.v.*, renal portal vein; *sc.v.*, sciatic vein; *sr.b.*, adrenal body. The ovary and fat body of the right side have been removed.

Thus in the gamete formation of the parasitic protozoön *Monocystis* individuals which produce male gametes encyst with those which produce female gametes; and at the breeding season males and females of the starfish *Asterina* are said to interlock their

arms. (2) Sometimes, as in many of the higher Invertebrates and lower Vertebrata, there are considerable differences in the ducts and other organs accessory to the primary genital organs (ovaries and testes), but only slight external differences, as in size, in the presence of holding and intromittent organs in the male, etc. Thus in the Frog, in which there exist between the organs which produce the gametes and between their ducts the very considerable differences which are represented in Figs. 183 and 184, the external unlikeness between the sexes consists in comparatively slight differences between the hands, those of the male being padded for clasping the female. In such animals the male usually seeks the female and either, like the frog, pours his sperm over her eggs as they are laid, or passes it into her body. The specialization of the sexes has increased. One, the female, plays in coition the same passive

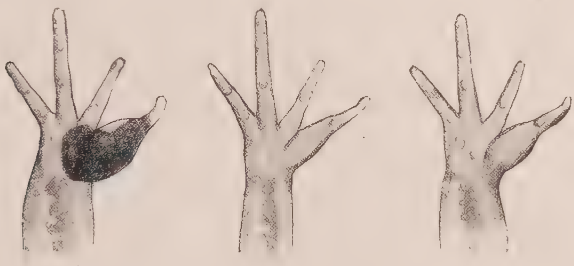


FIG. 185.—The palm of the right hand, *A*. of a male frog at the breeding season, *B*. of a female, *C*. of a male out of the breeding season.

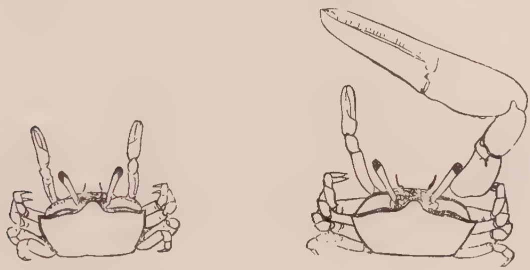
part which the germs she forms play in conjugation. The other, the male, plays the active part in coition and forms germs which play the active part in conjugation. Holding-organs, which first appear in animals at this stage in the differentiation of the sexes, are usually developed, as in the Frog, from paired appendages, though often, as in many arthropods, from only one of a pair. Intromittent organs may be "penes," developed from the terminal part of the vas deferens or from the part of the body upon which it opens, or paired appendages, as in various arthropods and elasmobranch fishes. Sometimes the intromittent organ is at a distance from the opening of the vas deferens, as in spiders, where it is on the pedipalps, and in octopoda, which use one of the arms (Fig. 196). Sometimes the sperm is transferred by an organ which is not "intromittent," since it does not enter the body of the female, but leaves the sperm on the surface of her body, as in the Crayfish.

Throughout the animal kingdom the rule prevails that, so far as there is a difference between the sexes, the male is the active organism, the female relatively passive. It is the part of the female to lay up the surplus material that she manufactures, in the form of germs provided with the protoplasm

FIG. 186.—The male and female of the Stag Beetle (*Lucanus cervus*).

which the zygote will require and stocked with yolk to serve as food in the early stages of its development. If either parent nourish the young in a brood-pouch it is nearly always she. In viviparous animals she must provide it with nutriment while it is an embryo, and in mammals it is she that feeds it with milk. The part of the male is freely to expend his substance in finding the

female, while the germs that he forms are poor in cytoplasm, but actively mobile to reach and enter the ovum. (3) In the highest animals, invertebrate and vertebrate, his activity is directed also to a lively and often hostile competition for her with other males. It is among these that he often possesses such ornaments and weapons as those of the male Stag-beetle and Stickleback, the Peacock and the Stag. Sometimes, in birds and mammals, he assists his mate by using his strength and weapons in her defence and by foraging for her. But it is in activity, not in size, or strength, or beauty that the true difference between the sexes consists; though the female is perhaps generally the larger and the male relatively the stronger of the two, and his greater physiological vigour often appears in the production of ornaments and weapons which are not found in the other sex.



A B

FIG. 187.—The male (*B.*) and female (*A.*) of *Gelasimus annulipes*, a fiddler crab.—From the *Cambridge Natural History.*

Concerning these weapons and ornaments of the male a vast amount of controversy has taken place without reaching any definite conclusion. They exist in very great profusion and variety. Even where there is no marked difference between the sexes in outward appearance the male has commonly in the highest animals brighter colours and better developed weapons than those of the female, but in many species he possesses organs and adornments, sometimes developed only at the breeding season, that are almost or altogether lacking in her. Of these, as of the differences and habits of the sexes in general, an excellent account may be found in those chapters of Darwin's *Descent of Man* which are devoted to "Sexual Selection." Here only a few conspicuous examples can be added to those already cited. The males of the Fiddler Crabs (*Gelasimus*), which are common on mud-flats in the tropics, have a large and brightly coloured pincer which is both an ornament and a weapon. Those of some beetles (*Phanæus*, etc.)

have upon the head and thorax great rhinoceros-like horns. The female of the Orange-tip Butterfly is without the splash of colour at the tip of the wing of the male which gives the species its name. The Silver-studded Blue (*Lycæna ægon*) has in the male wings of a fine purple-blue bordered with black, but in the female they are smoky-brown. The British fish known as the Golden Skulpin, one of the Dragonets (*Callionymus*), is in the male yellow with spots and stripes of blue, and has a long slender horn on his first dorsal fin, while the female is of a dull brown, without the horn on the fin. The Great Crested Newt of Britain (*Triton cristatus*), at the

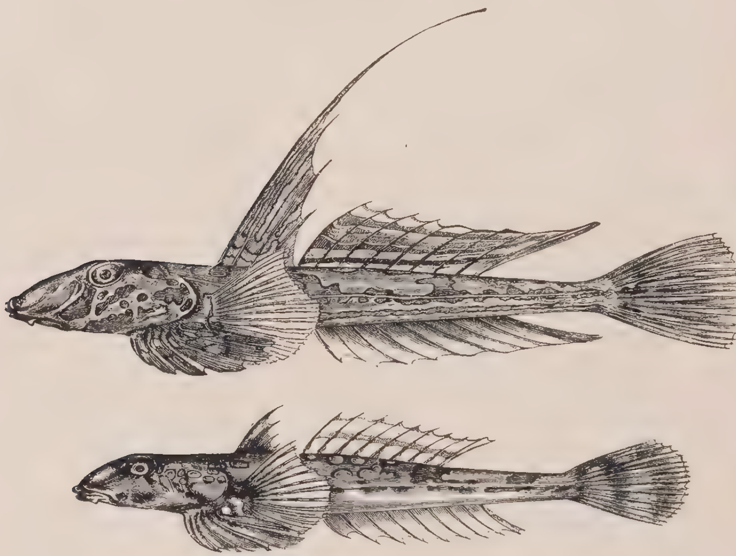


FIG. 188.—The male and female of the Golden Skulpin (*Callionymus lyra*).—From Darwin.

breeding season, is brighter coloured than the female and has along his back and tail a high, saw-edged crest which she does not possess. The male Sitana Lizard of India has under the throat an expansible pouch, brilliantly coloured in the mating season, which is lacking in the female. Owen's Chameleon has three long horns on the head of the male only. The spurs and ornamental plumage of the male of the Domestic Fowl are well known. In pheasants the difference between the sexes is still more striking, especially in such species as the Golden Pheasant and Argus Pheasant. To mention only one more of the numerous instances that might be drawn from the

birds, the gorgeous Birds of Paradise are the males of their species. The antlers of deer and the brightly coloured skin of the face and hinder part of the body of the male Mandrill are examples from among the Mammalia. Secondary sexual differences are not always differences of form and colour. Not infrequently the voice is louder in or confined to the male, as in the "belling" of stags, the howling of the Howling Monkeys (*Mycetes*), the croaking of frogs, the song of birds, and the chirping of grasshoppers. In other cases scent glands are peculiar to or better developed in the male, as in the Musk duck (*Cairina moschata*), the Goat, etc. The behaviour of the

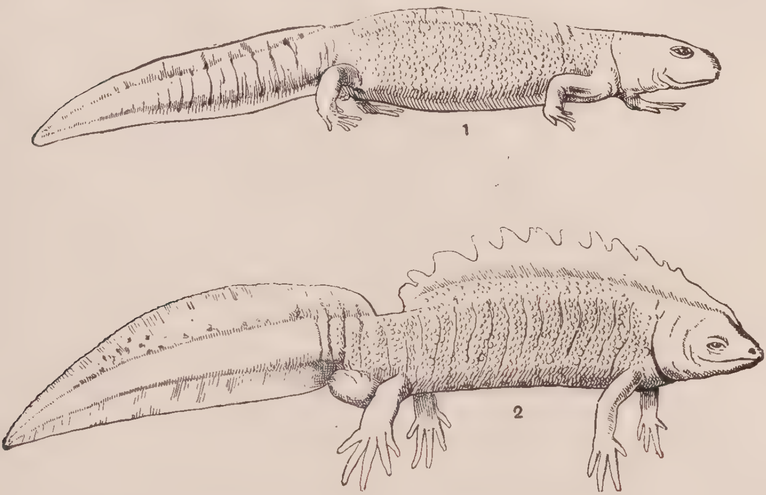


FIG. 189.—The female and the male, at the breeding season, of the Warty Newt (*Molge cristata*).

male in courtship is another sexual character. The strutting and bowing of the Pigeon and the display of the Peacock are well known. In other birds, notably in some pheasants, the love-dance is more elaborate. It is always adapted to show off the plumage to the best advantage. Similar behaviour has been noticed in certain fishes; and the males of many spiders perform a love-dance as elaborate as that of any bird. Dr. and Mrs. Peckham's description of this dance as it is performed by *Saitis pulex* has more than once been quoted in zoological literature, but we cannot refrain from giving it here, to show how complex a business is the mating of these animals. "He saw her," says Dr. Peckham, "as she stood perfectly still twelve inches away; the glance seemed to excite

him, and he moved toward her; when some four inches from her he stood still, and then began the most remarkable performance that an amorous male could offer to an admiring female.

FIG. 190.—The male and female of the Great Bird of Paradise (*Paradisea apoda*).

She eyed him eagerly, changing her position from time to time so that he might be always in view. He, raising his whole body on one side by straightening out the legs, and lowering it on

the other by folding the first two pairs of legs up and under, leaned so far over as to be in danger of losing his balance, which he only maintained by sidling rapidly towards the lowered side. The

FIG. 191.—A male argus pheasant displaying before the female.—From Darwin.

palpus, too, on this side was turned back to correspond to the direction of the legs nearest it. He moved in a semicircle for about two inches and then instantly reversed the position of the legs and circled in the opposite direction, gradually approaching nearer and nearer to the female. Now she dashes towards him, while he,

raising his first pair of legs extends them upward and forward to hold her off, but withal slowly retreats. Again and again he circles from side to side, she gazing towards him in softer mood, evidently admiring the grace of his antics. This is repeated until we have counted a hundred and eleven circles made by the ardent little male. Now he approaches nearer and nearer, and when almost within reach whirls madly around and around her, she joining and whirling with him in a giddy maze. Again he falls back and resumes his semicircular motions, with his body tilted over; she, all excitement, lowers her head and raises her body so that it is almost vertical; both draw nearer; she moves slowly under him, he crawling over her head, and the mating is accomplished."

The meaning of these features is, as has been said, a matter of much dispute. About the weapons there is less difficulty than about the others. They are used sometimes in the performance

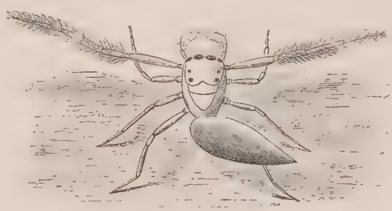


FIG. 192.—A male of the spider *Icius mitratus* in the dancing attitude.—From Warburton, after Peckham.

of the duty of the male to protect the female, and sometimes in his contests for her with other males. As to the other special characters of males three hypotheses have been put forward. One of them is Darwin's theory of Sexual Selection, according to which they serve to attract the female and cause her to select as her mate the male in which they are best developed. Unfortunately for this theory, while there is no doubt that the female often exercises a choice between a number of suitors, there is little evidence that she is guided in this by the characters we are discussing, however much they may attract human attention. Such experiment as has been made upon the subject—on lizards and moths—lends the theory no support. It is indeed unlikely that, for instance, moths, in which secondary sexual characters are often conspicuous and the males will often crowd round a female, have the psychology which would make such a choice as is supposed. A second attempt to explain the facts is Wallace's theory of Recognition Marks, which classes sexual

ornaments with a number of other features in the colouring, etc., of animals as a means whereby members of the same species recognize one another, either, as in markings common to the sexes, in order to keep a herd or covey together, or, as in sexual features, to avoid unfertile crosses. That such markings occur in one sex only is due, according to Wallace, to the necessity for protective colouring in the female to whom belongs mainly the care of eggs and young. This theory meets with difficulties of the same kind as those which stand in the way of the theory of sexual selection. A third hypothesis regards male ornaments, etc., merely as an expression of the more vigorous physiology of the sex, but fails to explain thus their definiteness and elaboration. Probably it is true that the almost invariably brighter colours and larger plumes, etc., of the male have a physiological cause, though what this cause may be is not clear; and that where there is between the sexes a great difference in such things, it corresponds to some necessities in the life of

FIG. 193.—The male (*A.*) and female (*B.*) of the Vapourer Moth (*Orgyia antiqua*).

the species. Protective resemblance probably prevents the female from following the fashion of her mate, but his conspicuous features, and often his display of them to the female, still require explanation. It is hard to resist the conclusion that they play some part in the relations between the animal and his surroundings, or that the particular relation they are concerned in is that between the sexes. Probably in some way they bring them together, though how they affect the psychology of the female is not clear.

As we have already seen, the part which the female takes in the joint task of the sexes is a passive and nutritive one. This is no doubt the reason why she is not only, as a rule, less conspicuous and well armed than the male, but is usually larger and has often less power of locomotion. The various insects, such as the Vapourer Moth (*Orgyia antiqua*) and the Glowworm beetle, in which the female only has no wings, are examples of this. In the Argonaut or Paper Nautilus (*Argonauta*), the female has long arms, two of which end in expansions that secrete the thin shell to which the

species owes one of its names. The male is very much smaller, lacks the arms which in the female secrete the shell, and has the

FIG. 194.—Males, females, and larvæ of the Glowworm (*Lampyris splendidula*).—From *Cassell's Natural History*.

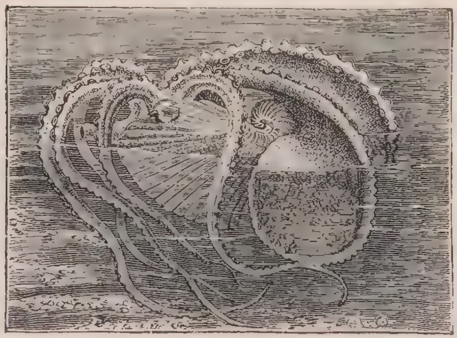


FIG. 195.—The female Paper Nautilus (*Argonauta*). —From Thomson.

others short, save one which is remarkably modified, being very long and coiled up in a sack till it comes into use, which it does to transfer the sperm to the female. In this act it is broken off and

lodged under her mantle. Still more remarkable instances of unlikeness of the sexes are provided by various parasitic Crustacea. The copepod *Lernæa*, for instance (Fig. 197), starts life as a free "nauplius" larva, and after a while becomes parasitic on the gill-filaments of a flatfish. Here it degenerates and is for a time without the power of movement. Later it regains this power and leaves its host as a free-swimming and sexually mature adult not unlike the common freshwater crustacean *Cyclops*, though it has, among other differences, a very long

FIG. 196.—The male of the Paper Nautilus.
—From Thomson, after Jatta.

body. Impregnation takes place in this stage, and the male dies. The female, however, seeks a fish of the cod family and, becoming attached to its gills, embeds the forepart of her body in the flesh. The rest of the body becomes twisted and worm-like, and the whole creature completely degenerate. In other parasitic copepoda, such as *Lernæopoda* and *Chondracanthus* (Fig. 122), there is no free mating stage, but the males are attached, as dwarfs which have remained at an early post-larval stage, to the body of the large, degenerate female. A similar arrangement exists in some of the parasitic isopods. In the echiuroid worm *Bonellia* the male is a minute and partly degenerate creature which lives as a parasite in

the uterus of the female. Sometimes, however, the male of a species is larger than the female. This is true of most mammals and birds. The males of the "Scuds" (*Gammarus*) and other amphipod crustaceans carry about the smaller females, each holding his mate under him with his claws. In the Blood Fluke (*Schistosoma* or

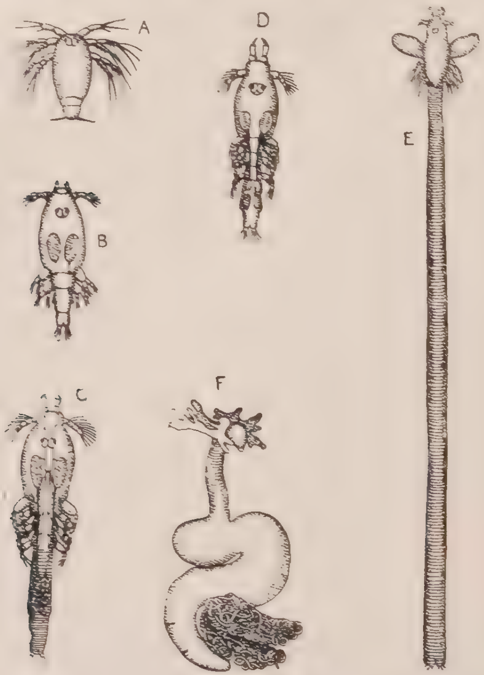


FIG. 197.—Stages in the development of *Lernæa branchialis.*—From Calman, after Scott.

F. is slightly, the other figures greatly enlarged.

A., Nauplius; *B.*, young female from gills of flounder; *C.*, free-swimming stage of female after leaving flounder; *D.*, free-swimming male; *E.*, female just after settling on gills of whiting; *F.*, fully developed female.

Bilharzia hæmatobium), the cause of bilharziosis in Man, she is borne in a groove on the ventral surface of his body.

Interestingly enough, features or habits, or both, are sometimes transferred from one sex to the other and may even come to belong to it alone. In the Reindeer the female as well as the male has horns, and the same is true of some horned beetles. Occasionally the male undertakes a part, or even the whole, of the labours that normally fall to the female. Fairly often he helps in

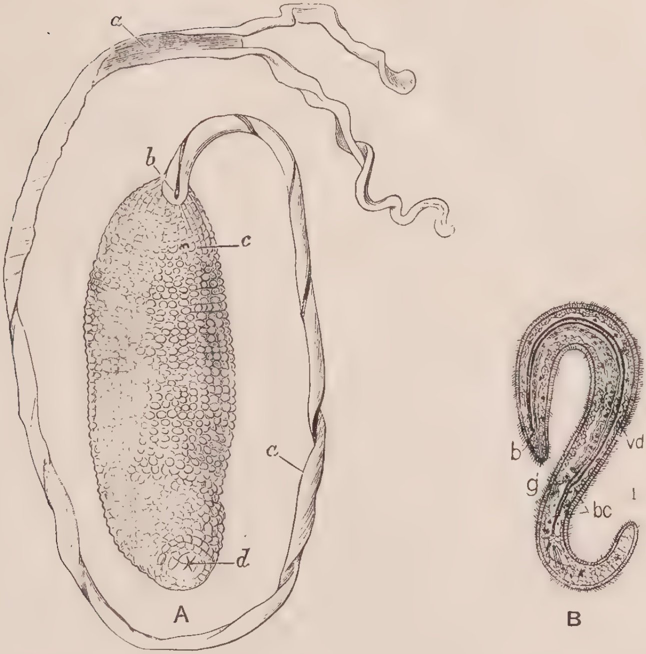


FIG. 198.—The male (*B.*) and female (*A.*) of *Bonellia viridis.*—After Shipley.
a., Proboscis; *b.*, mouth of female; *b′*, blind anterior end of alimentary canal of male; *b.c.*, body cavity; *c.*, ventral hooks; *d.*, anus; *g.*, external opening of vas deferens; *v.d.*, vas deferens. The short line to the right of the male indicates his natural size. The figure of the female is of natural size.

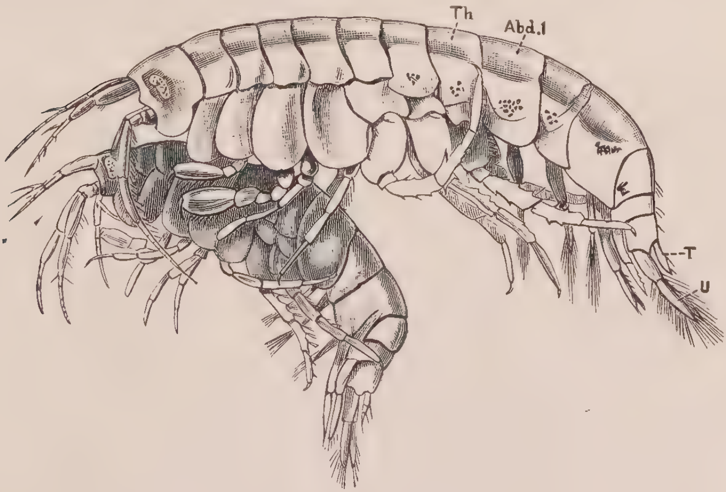


FIG. 199.—The male of *Gammarus*, carrying the female.—From the *Cambridge Natural History.*

the care of the offspring; and in some birds, as in the Pigeon, he takes his share of sitting upon the eggs. More seldom he alone carries them, as in the frogs that we have mentioned, and the Sea

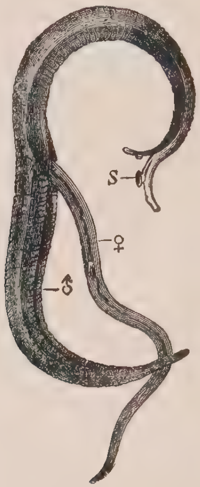


FIG. 200.—*Schistosoma hæmatobium.*—From Sedgwick.
♂, male; ♀, female; *S.*, sucker.

FIG. 201.—The male of *Nymphon stromi* (Pycnogonida), carrying egg-masses on his ovigerous legs. –From D'Arcy Thompson.

Spiders (*Pycnogonida*), or has charge of the young, as in the Stickleback (p. 130). Very exceptionally the rôles of the sexes are reversed, in that it is the female that courts the male. This happens, for instance, among birds, with the Dotterel (*Eudromias*

morinellus), whose male also hatches and rears the young. The Cabbage White (*Pieris brassicæ*) is an example among butterflies. In such cases the female is usually more brightly coloured than the male, though she is never as conspicuous as the males of highly adorned species.

The association of the sexes for reproduction may last only until impregnation has taken place, or until the breeding season is over, or until the death of one of the partners. In it one male and one female may suffice each for the other; or, the numbers of the sexes

FIG. 202.—The male of *Boreonymphon robustum*, carrying young.—From the *Cambridge Natural History*.

being approximately equal, each female may be impregnated upon different occasions by several males; or there may be fewer males than females, so that each male suffices for several females, whether these live separately or together with the male; or, less often, as in the sexual barnacles, each female may require several males. Finally, for one or more generations, males may be absent, and the females reproduce by parthenogenetic development of their ova.

Parthenogenesis does not confer the benefit, whatever that may be, which accrues from conjugation, but has the advantage of simplifying the process of reproduction even more than herma-

phroditism does, and thereby of shortening the time required to produce a generation. It is known to take place occasionally in a number of species for which it has probably no great significance, but most animals in which it occurs regularly (many branchiopod and ostracod crustaceans, plant-lice, hymenoptera and other insects, rotifers, nematode worms, etc.) produce large numbers of short-lived individuals in a limited season. The appearance of males and consequently of sexual reproduction in species which

FIG. 203.—The male Dotterel sitting on the eggs.—From Seton Gordon.

practise parthenogenesis often coincides, as we have noted (p. 18), with the onset of unfavourable conditions during which the species will suspend reproduction. Thus various plant-lice produce males towards the end of the growing season of their food-plant, and certain cladocera do so in a similar period of scarcity or when the temperature falls. Conjugation, however, is in these cases probably in some way a preparation for a future period of multiplication rather than for the intervening time of endurance, and the appearance of males in parthenogenetic species is by no means confined to seasons of hardship.

CHAPTER VII

FAUNAS: THE WATER FAUNA

THE animals which dwell in any locality or kind of locality are together known as its *fauna.* Thus we can speak of the fauna of England or of the desert fauna. Faunas are of two sorts—*geographical faunas*, which belong to localities, and *œcological faunas*, which belong to kinds of locality. These, of course, are cross divisions, for most local areas have sub-localities of different kinds—as England has mountains, plains, and fresh waters—and most kinds of local conditions turn up again and again in different places—as, for instance, do those of pieces of fresh water, which have much in common in all countries in which they are found. The kinds of animals which make up a geographical fauna are determined by the facilities which there are or have been for migration to it—for example, by land connections which in the past allowed the entry of certain animals but disappeared before others were evolved—or for evolution within it; and such a fauna has no features which are common to all its members, except in so far as it may happen to be also an œcological fauna, which it will be when the locality is throughout of one type. Thus the faunas of the Sahara and of Windermere are both geographical and œcological faunas, and each has certain features common to most of its members; but the fauna of England is a geographical fauna only, and those of its members which live in Windermere have less resemblance to those which live on Helvellyn than to animals which live in Lake Constance, or even Tanganyika. An œcological fauna, on the other hand, has certain features which appear in different forms in most or all of its members, however unrelated they be in descent, and enable them to live in the conditions in which they pass their lives together, as, for instance, the great majority of the members of the freshwater fauna are organized to breathe water, and many of them to swim. Since we are studying the relation of animals to their present surroundings and not their history, our concern is with œcological rather than with geographical faunas.

Œcological faunas are classified, in the first place, according

to the most important of the factors in their surroundings, the medium, into three divisions—those of the Water, those of the Land, where air is the medium, and that of the interior of the bodies of organisms, *i.e.* the Internal Parasites.[1]

Water is the natural home of living beings, and there is no doubt that life started in it. It is an essential constituent of the bodies of organisms, and in various ways their life is more easily carried on in it. (1) *Within the organisms* it is of importance both as a constituent of protoplasm and as a circulating medium. (i) As a *constituent of protoplasm* it is in the first place essential as a *solvent*. There is no other liquid which dissolves such a number and variety of substances. What is of equal importance is that upon most of them it exerts no *chemical action*. On the other hand, it is capable of very important chemical reactions with its solutes in the presence of suitable catalysts (the enzymes), by which therefore these actions can be controlled. Again, water produces a greater amount of *dissociation of its dissolved substances* into ions[2] than almost any other solvent, and thus enables all kinds of reactions to take place which do not occur between them in their molecular state. Its own hydrogen ions are powerful catalysts in causing reactions in which they themselves do not take part. Again, it has a higher *surface tension*[3] than any other liquid except mercury, and thus makes possible for protoplasm many kinds of surface action, mechanical, chemical, and physical, which play a very great part both in the internal and in the external physiology of organisms. From our point of view, the most important of these actions are that

[1] Of the several parts of the earth's surface in which the various œcological faunas dwell, those of the first rank are distinguished by characteristics due to the medium, either directly or indirectly, owing to its influence on light, temperature, moisture, and so forth. This is true even of some, such as deserts and forests, which at first appear to be characterized by their substratum and the vegetation upon it. Since regions which differ thus may be said, very broadly speaking, to succeed one another in vertical belts from the abysses of the sea to the peaks of the mountains, the term *zones* which is sometimes applied to them is appropriate, and by analogy the same term may be applied to the habitat of internal parasites. In each zone minor types of habitat are distinguished by differences of the substratum and of the vegetation which it supports, as both deserts and the littoral zone of the sea have rocky and sandy parts. Such habitat types are known as *facies*, and their faunas as *associations*.

[2] The molecules of many substances are, in certain solvents, broken up into smaller groups of atoms, known as *ions*, which, upon occasion, will combine to form new substances that could not have arisen from the original compounds without such decomposition.

[3] The surface layer of a liquid, owing to the attraction of its molecules for one another, behaves as though it were a skin, stretched over the rest of the liquid and retaining it by tension.

taking up and holding back of substances at the surface of protoplasm which are essential to its life, and the forming of membranes, cuticles, and shells by which it is protected. Water is also a very valuable constituent of protoplasm in virtue of its *relations to heat*. It has the highest heat capacity (specific heat) of all substances which are solid or liquid under ordinary conditions of temperature and pressure. That is, to raise the temperature of any mass of it by any number of degrees requires more heat than will warm equally the same mass of another substance. In consequence of this, the heat produced by the contractile and other activities of protoplasm does not cause an injurious rise in temperature before it can be got rid of at the surface of the body. Water is a good conductor, for a non-metallic substance, which makes easy the transference of heat within the body when convection is not possible; and its high latent heat of evaporation facilitates cooling at surfaces exposed to air. Finally, its *transparency* is a valuable property in eyes, and in animals which contain symbiotic plants. (ii) As a *circulating medium* it has the advantages of not being very viscous and of being a good solvent. In short, there is no other substance that could take the place of water in the organism, and without it life, as we know it, would be impossible. (2) *As a medium* for animals, water has several advantages.[1] (i) In the first place, it is an ever-present supply of what we have just seen to be an *indispensable material*, and this can often be absorbed by animals that live in it, through the surfaces of their bodies. (ii) In it changes of *temperature* take place less rapidly and within narrower limits than in air. This is due to more than one of its properties. Its high capacity for heat, and latent heat of evaporation, which have already been mentioned, are of importance here also. It is less permeable to the radiant energy of the sun than is air, and its permeability does not vary, as does that of air, with the amount of water vapour which is present. Its great latent heat of melting, set free when it freezes, causes it to solidify slowly and keeps it meanwhile from falling below its freezing point, and as this is comparatively high, it allows many chemical reactions to go on. On the other hand, when the temperature tends to rise and the ice is melting, absorption of the same amount of latent heat prevents

[1] Water is here compared with air; but the fact may be noted that, in virtue of various properties (thermal, solvent, translucent, etc.), it has an advantage over every other substance, liquid as well as gaseous, that might have been the medium for animals, and that in fact it is the only liquid medium in which life as we know it could proceed, just as it is the only possible internal fluid for organisms.

the water from being warmed too suddenly. Since fresh water expands between 4° C. and 0° C. and again on freezing, the cold water is lighter and remains at the top, so that the deeper layers rarely fall to freezing point. Thus several of the peculiarities of water combine to prevent in it extremes of heat and cold. How effectively they do so may be seen in the fact that the known range of temperature in the sea is only 39° C. (from – 3·5° C. to 35·5° C.), whereas that on land is more than 120° C. On the other hand, though in water radiation is less than in air, and evaporation, of course, impossible, the internal temperature of animals immersed in it is kept from rising by its comparatively high conductivity and by convection,

FIG. 204.—*Portunus depurator*, a swimming crab.—From Calman. Note the paddle-like hinder pair of legs.

which is the more effective on account of its high capacity for heat. It is, no doubt, because of their more equable conditions of temperature that water animals are almost without exception[1] poikilothermic ("cold-blooded"), and that homoiothermic animals are found only among the land fauna, which lives in a medium in which the power of maintaining an even internal temperature is a valuable asset. For a similar reason water animals are less eurythermal than those of the land.

(iii) Owing to the *density* of water, the skeletons of its fauna need not be so strong as those of animals which live in air, swimming

[1] The exceptions are animals which, like the whales, are descended from members of the land fauna.

animals can support themselves with less expenditure of energy than those that fly, and floating is possible as it is not in air. The water fauna may be divided into the *Benthos,* which is rooted or crawls upon or burrows into the substratum, and comprises such creatures as zoophytes, worms, crabs, whelks, and starfishes; the *Nekton,* which swims strongly, as fishes, squids, and whales; and

FIG. 205.—*Zoothamnium niveum*, a colonial vorticellid.—After Saville Kent.

the *Plankton*, which drifts or swims feebly, as many protozoa, jelly fishes, various small crustaceans, and the larvæ of many members of the benthos and nekton. (*a*) *The benthos* may again be divided, either by its powers of movement, into fixed or *sessile* forms, and those that move about and are therefore said to be *vagile,* some of which, as the Swimming Crab (*Portunus*), move partly by swimming and partly by crawling, while others, as the Whelk, only crawl; or, in another way, more or less vertically, into the actively

vagile or *wandering fauna*, such as crabs and starfishes, the *sedentary* or *sessile fauna*, and the *cryptozoic* and *burrowing faunas* about which something has already been said. (α) In a later chapter (p. 272) we shall have occasion to deal with walking and crawling animals. (β) That *sessile animals* are found in water and not in air is no doubt due to the facts both that the support which the medium affords allows the construction from animal tissues of the plant-like body which their habit involves, and that there is available in the medium a good supply of floating and swimming food. The more powerful and constant currents of the water perhaps also present to the members of its fauna an inducement to anchor themselves which

Fig. 206.—The Red Coral (*Corallium rubrum*).—From *Cassell's Natural History*.

is lacking in the air. Sessile animals may stand without skeleton, as do the Vorticellid Protozoa, the Sea Anemones, and *Hydra*; or they may have an internal skeleton, as do the Sea Pens (*Pennatulida*), Red Coral (*Corallium*), and Sea Lilies (*Crinoidea*); or they may have external support from a coral underneath them, like that of the Madrepores, or from a cuticle, like those of the Hydroid Zoophytes and Polyzoa and the firm, leathery tunic of the Sea Squirts (*Ascidiacea*, Fig. 236), which serves also as a protection. Often they build tubes which are protective without being skeletal (Figs. 92. 210). They may be able to move about (subsessile) like *Hydra*, sea anemones, and such ciliate protozoa as *Stentor*; or permanently fixed in one spot like the Hydroids and Corals; and in the latter case their

growth is affected like that of plants by such circumstances as the amount of food available, the purity of the water, and the direction of the prevailing current. Something has already been said (pp.

FIG. 207.—Part of a branch of the Red Coral, with the soft tissues dissected away to show the hard axis.

43–47) of the various ways in which, by tentacles, sieves, etc., they gather their food. Since they do not pursue it in any direction, but glean it equally from all sides, there is a strong tendency among them to become radially symmetrical. Since they expend little energy

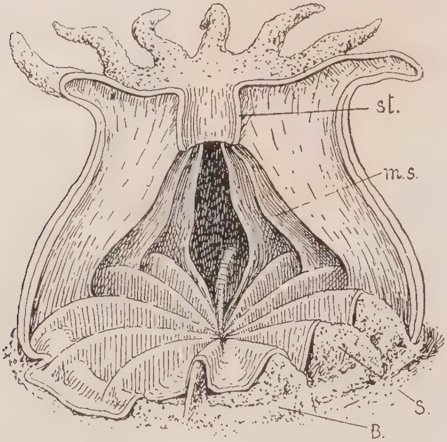


FIG. 208.—A polyp of the coral *Astroides*, dissected to show the relation of the soft parts to the hard skeleton upon which it is seated.—From Thomson, after Pfurtscheller.

B., Rudiment of theca ; *ms.*, mesentery ; *s.*, septum ; *st.*, stomodeum or gullet.

FIG. 209.—*Stentor*.

in movement, a great part of the material which they assimilate is available for growth and reproduction. If it be expended in growth, it usually leads by budding to the repetition of the original body or zooid which resulted from the development of the ovum, and thus arise colonies of zooids, such as are formed by many of the animals we have mentioned (Figs. 211, 265). Such colonies may be encrusting, like lichens, or branched, like ordinary plants. Vagile animals are rarely colonial, and when that happens it is almost always an indication of descent from sessile

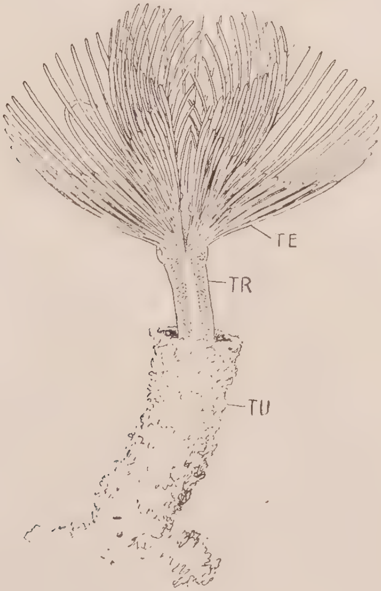


FIG. 210.—*Phoronis*, much enlarged.—From Thomson.

TE., Tentacles; *TR.*, trunk; *TU.*, tube.

ancestors. It can hardly be doubted, for instance, that the swimming colonial tunicate *Pyrosoma* is descended from fixed colonies of ascidians, or that the temporary hanging together in chains of the sexual individuals of *Salpa* is the last trace of this habit; and the crawling colonies of the polyzoön *Cristatella* must at one time have been fixed like their forebears. It is perhaps the habit of building new bodies by the growth of tissues without passing each time through an egg stage that causes asexual reproduction, by the setting free of medusæ, gemmules, statoblasts, etc., to be common among sessile animals. While wandering animals may, and often do, fix

their eggs in one place (p. 129), or pass through a young stage that is no more, or even less, mobile than the adult, the young of sessile creatures must travel actively or passively in order to distribute

FIG. 211.—Part of a colony of *Obelia*, magnified.

bl., Blastostyle; *ect.*, ectoderm; *end.*, endoderm; *gth.*, gonotheca; *hyth.*, hydrotheca; *med.*, medusa bud; *p.b.*, polyp bud; *perith.*, peritheca.

the species (p. 340). This they generally do as members of the plankton.

(*b*) *Swimming* organs are of many and very various kinds. In a few cases, water is forced from the body by the narrowing of a

cavity, and thereby the animal is driven in the opposite direction. This is done, for instance, by the contraction of the "umbrella" of a jelly-fish, the sudden closing of the shell of the Scallop (*Pecten*,

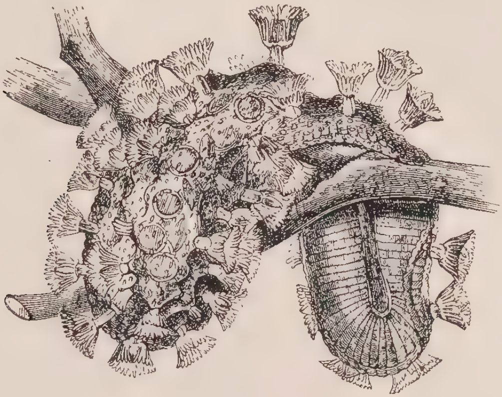


FIG. 212.—A colony of *Cristatella*, crawling.—After Allman.

Fig. 233), and some other bivalve shellfish, and the driving of water from the siphon of cuttlefishes by the contraction of their mantle. Octopuses add to the action of the siphon that of the

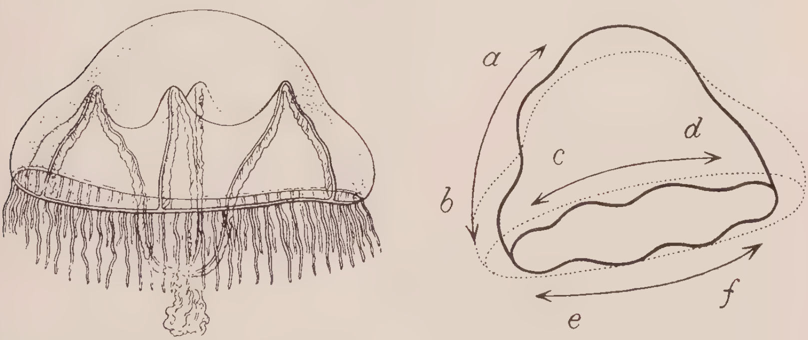


FIG. 213.—The hydroid jelly fish *Tima flavilabris*, and a diagram of its movements during swimming.—From Pettigrew.

The heavy line in the diagram shows the movements, the dotted line gives the outline of the animal at rest. During the effective stroke (narrowing of the bell) waves of contraction pass in the directions *a–b*, *c–d*, *e–f*; during the non-effective stroke (expansion) the waves are in the opposite direction.

webbed arms whose opening and closing has the same effect as the similar movement of the jelly-fish's umbrella. In other swimming animals, the water is struck either by the whole surface of a great part of the body—as in flatworms, flatfishes

like the sole, rays, which use the immense fore-fins that border their bodies, and eels or by appendages of various kinds, such as cilia and organs formed by their fusion, annelid and arthropod limbs, the fins of a squid, the arms of the Feather Star (*Antedon*, Fig. 46), and the tail of fishes and whales. In all these the organ used makes two strokes—a non-effective or back stroke, in which it presents a convex side to the water and often is

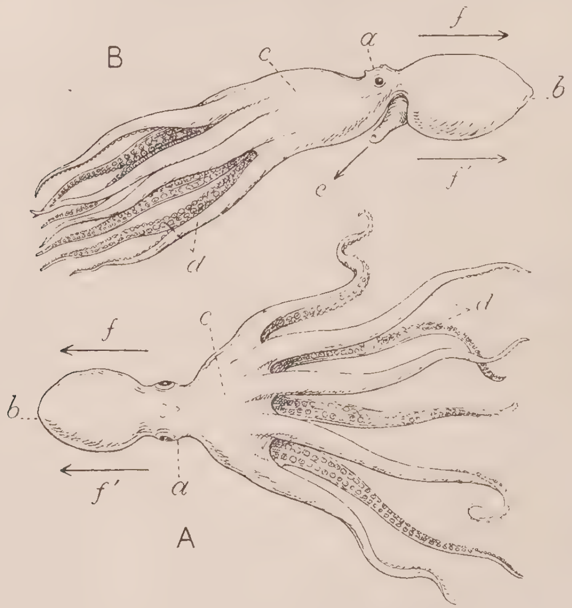


Fig. 214.—The Common Octopus (*Octopus vulgaris*) in the two phases of swimming.—From Pettigrew.

A., The arms are spread, in the non-effective or back stroke ; *B*., the arms are brought together in the effective stroke.

a., Head of octopus ; *b*., its body ; *c*., web of arms ; *d*., outer and inner surfaces of arms ; *e*., siphon, with arrow showing direction of water passing through it during forward stroke ; *f*. *f′*., line of advance.

more or less folded or turned edgeways, and an effective or forward stroke, in which it presents a concave biting side to the water, and is expanded if it have been folded in the back stroke. Sometimes the power of the effective stroke is derived from, or increased by, the rebound of an elastic structure, such as the notochord, in which energy has been stored by its bending during the back stroke. In fishes there are two simultaneous movements of the tail, both of which have the general features we have just described. The tail is moved from side to side, and at each stroke it rotates about its

long axis, so as to screw as well as to row the body forward. Sometimes, in stout-bodied fishes, the screwing movement does the principal part of the work. In many cases there are balancing and steering fins, such as the paired and back fins of fishes.

(c) *Floating animals* and, what are more common, animals whose

Fig. 215.—Phases in the swimming of a ray.—From Marey.

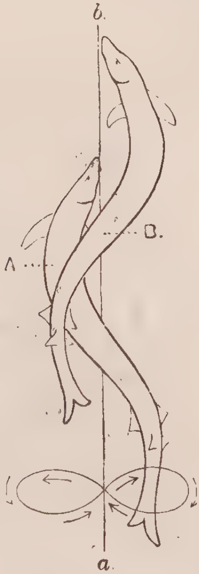


Fig. 216.—A diagram to illustrate the mode in which the tail of an ordinary fish is used in swimming. — From Bridge.

A. and *B.*, Two successive positions in swimming along the line *a. b.*

powers of swimming are feeble, are hindered from sinking by various expedients, which may be classed under three heads—increase of the surface offered to the water by spines, etc.; decrease of the density of the tissues; and the carrying of some substance, such as gas, or oil, or fresh water of less specific gravity than the surrounding medium. Further details concerning these

will be given in a later chapter (p. 239). With the floating animals live plants of the same habit, and together these organisms make up an assemblage as various and remarkable as that which dwells upon any substratum. Its members differ greatly in size. The larger of them, such as the great jelly-fishes and salps, which may be taken in large, wide-meshed nets, are known as the *Macroplankton*. Smaller organisms, such as many of the crustaceans, appendicularian tunicates, larvæ, and protozoa of some size, caught in small-meshed nets, are the *Microplankton*. The smallest, comprising little plant-flagellates (Figs. 61, 228), and diatoms bacteria, spermatozoa, etc., which pass through the meshes of the finest

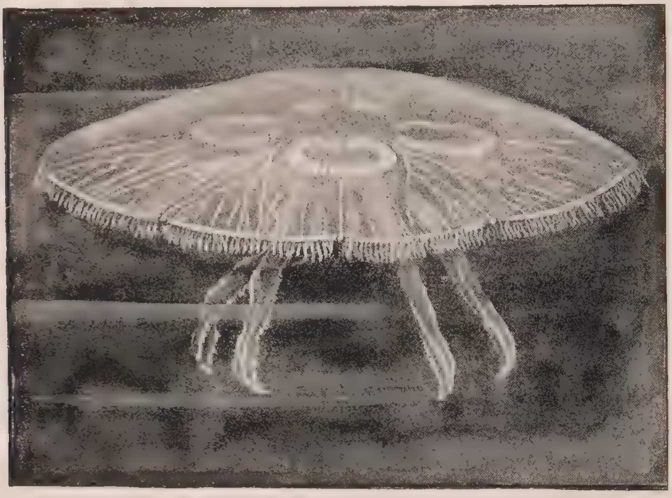


FIG. 217.—The Common Jelly-fish (*Aurelia aurita*).

nets, are the *Nannoplankton*. In virtue of the plants which largely compose it, and upon which, directly or indirectly, its animal members are principally nourished, the plankton is, as we shall see, of great importance as a source of food. Within it, the smaller organisms serve to nourish the animals of intermediate sizes, and the medium-sized organisms similarly feed the larger; while the plankton as a whole is, at least in the sea, the chief source of nourishment for the nekton and benthos. As may be gathered from this fact, it is immensely plentiful, and only its inconspicuousness causes it to be comparatively unfamiliar. (*d*) Plankton, nekton, and benthos are not sharply distinct, for, of course, there are many crawling animals that also swim, and even the most powerful swimmers are at the mercy of a strong current. In the air there is

nothing that, in its independence of the substratum, can be compared either to the nekton or to the plankton, and if flying animals resemble the nekton in travelling through the medium, there is nothing at all that floats—unless that can be said of the young of certain spiders that are blown through the air hanging from gossamer threads of silk, or of the cysts of minute organisms that are air-borne as dust. For all sections of the water fauna, reproduction by the dissemination of ova and spermatozoa naked in the medium is possible, as it is not in air, both because the gametes can float and swim in it, and because in it they are not killed by loss of water in evaporation.

(iv) That *evaporation does not take place* from the bodies of

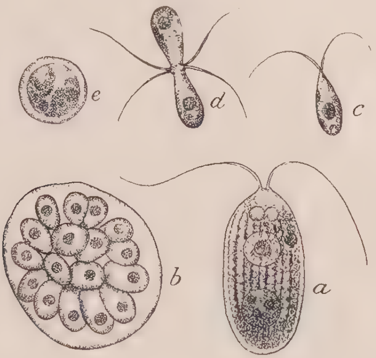


FIG. 218.—*Chlamydomonas steini*, a freshwater plant flagellate.

a., Ordinary individual ; *b.*, gametes still enclosed in the cuticle of the individual from which they arose by fission ; *c.*, a free gamete ; *d.*, conjugation ; *e.*, the zygote.

animals immersed in water is also important, because it relieves them from the necessity of forming a cuticle, save when it is required for protection from other dangers, or as a skeleton. On the other hand, it is a disadvantage in that it deprives them of a means of disposing of surplus heat. (v) The high *surface tension* of water, to which allusion has already been made (p. 178), is, of course, a thing to which there is nothing corresponding in the gaseous medium. Since animals live only near the bottom of the air ocean, comparison in this matter is impossible, but it may be remarked that in no other liquid could animals skate upon the surface as insects (*Hydrometra*, etc.) may be seen to do in any pond, or hang from it, as do snails, gnat larvæ (Fig. 269), and other animals. Mosquito larvæ even gather their food from the surface film, sweeping small organisms and other particles from it with the pair of food-collecting

brushes which they bear upon their heads, and from which the catch is combed, for swallowing, by the mandibles and maxillæ.

(vi) Finally, owing to its *power of bearing substances in solution*, animals that live in water are able, unless they cover themselves with an impermeable cuticle, to exchange not only gases but also other materials with the medium upon the surface of their bodies. Generally this exchange is limited by the presence of a thin but visible secreted membrane, such as that which covers the gills of crustacea, or pellicle formed by the transformation of the surface layer of the protoplasm, as in most uncuticulate protozoa, cœlen-

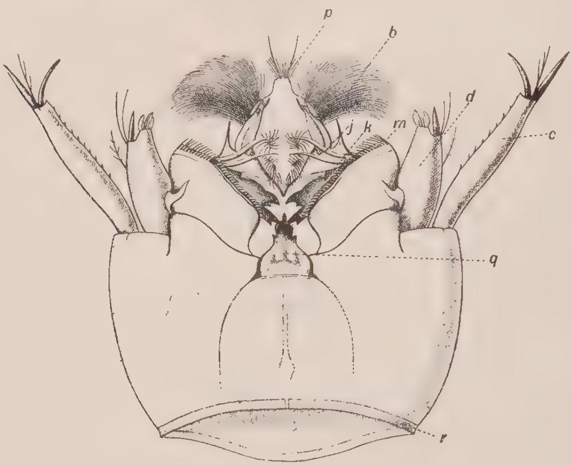


FIG. 219.—A ventral view of the head of a fully grown larva of *Anopheles maculipennis*, a mosquito.—From Nuttall and Shipley.

b., Brush with which food is swept from the surface film; *c.*, antenna; *d.*, palp of maxilla; *j.*, stout hairs of mandible which arrange the brush; *k.*, teeth of mandible; *m.*, hooked hairs at edge of maxilla; *p.*, a medium tuft of hair; *q.*, the under lip (metastoma); *r.*, rim of head.

terates, echinoderms, worms, etc., by which the passage of substances to and from the body is to some extent hindered. In a few cases the protoplasm is apparently naked; but even then it retains a certain control over its exchanges with the medium, owing to its power of behaving as though its surface were a delicate membrane (p. 20), which resists the passage of certain substances while, in some way that is not understood, it permits that of others. But this power is limited and liable to be overcome, to the detriment of the organism. The several exchanges which take place between the bodies of water-living animals and the surrounding medium need separate consideration. (*a*) Since gases can only pass in and out through a membrane that is wet upon both sides, air-breathing animals

must keep the surface of their organs of respiration damp. It has been shown,[1] for instance, that this is done by the Land Hermit Crabs (*Cœnobita*). Water breathers are relieved from this necessity. On the other hand, there is less free oxygen in water than in air; and what there is diffuses less readily, so that its amount differs more from time to time and from place to place. In this respect air has the advantage. (*b*) Again, it has been proved [2] that sea water contains organic substances, probably produced in the bodies of its microsopic algæ and diffused thence, and it is likely that the same is true of fresh waters. Experiments of Pütter and others make it very probable that many aquatic animals obtain part of their nourishment by absorbing these, perhaps sometimes through their gills. These observers find that the amounts of carbon which are taken in an organized form by various animals (sponges, small polyps, copepods, fish larvæ, etc.), and the rates at which the latter digest, are far too small to maintain the output of carbon dioxide which the animals are proved to have; and that individuals of certain species (of holothurians, cladocera, etc.), when they are kept in filtered water, are able to live for long periods, and sometimes even to breed, without solid food; moreover, the amount of dissolved organic matter in the water in which animals are kept has in some cases (ascidians, sea-anemones) been shown to be lessened after a time. It may be that this is a hitherto overlooked factor of very great importance in the nutrition of the water fauna.[3] (*c*) There is little doubt that animals which are not provided with special organs of excretion, and perhaps some of those that are, shed excreta directly from the surface of the body into the water; and it is in any case an advantage that such substances can be taken up and borne away by the medium. (*d*) Both salts (including acids and alkalis) and water are undoubtedly exchanged between the medium and the bodies of water-living animals that are naked, and, it would seem, also pass to and from many of those that are cuticulate—perhaps in that case through the gills. The concentration of salts in the blood and other body-fluids of many marine animals is approximately that of the water in which they are living, and this is probably because there would be difficulty in maintaining any other.[4] Many of these substances are indispensable constituents of the body.

[1] Gardiner's *Fauna of the Maldives and Laccadives*, vol. i., article "Land Crustaceans."

[2] Pütter, Raben, Natterer.

[3] See footnote to p. 313.

[4] It is likely, however, that the taking up of substances in solution in the medium is an active physiological process, and not merely an adjustment of physical equilibrium on the two sides of a membrane.

It is doubtful, however, whether the presence of salts in the medium be not as much a danger as an advantage, for salts play very important parts in the physiology of an organism, and its economy becomes attuned to a certain salinity so that naked animals are often extraordinarily sensitive to small changes in the composition of the water around them. The salinity of waters affects their indwelling organisms in several ways. (α) According to the total concentration of salts, water will tend to pass to or from the body. When the osmotic pressure is higher than that within the organism, water will tend to be withdrawn; when it is lower, water will enter. With this is probably connected the more frequent presence in fresh water than in marine or internally parasitic protozoa of contractile vacuoles, which are as much water-pumps as excretory organs. (β) Individual salts or their ions in the medium have specific effects upon the organism. Some of them take action upon the surface of the body without ever entering it, or, if they enter, without exercising any influence after they have done so. This is doubtless due to their effects upon the surface film. Thus sodium hydroxide doubles the consumption of oxygen in the eggs of sea-urchins without entering the cell; and produces great changes in behaviour, and finally death, in *Paramecium* in a similar way. In other cases, however, the specific effects of salts are exercised within the organism, as upon the activity of enzymes, upon the dissociation of oxyhæmoglobin, upon the movements of the pigment in pigment cells, upon the apparatus by which cilia and flagella are worked, and (by affecting the condition of colloid substances, of which protoplasm is largely composed) upon the stability of various cell mechanisms and upon such processes as the clotting of blood. Calcium, in particular, has extremely important effects upon many vital processes, and the same is true of potassium, whose action is, as a rule, of an opposite kind to that of calcium; but the ions of sodium, magnesium, and other metals have also much influence. Probably, however, the most important of all ions are those of hydrogen and of hydroxyl, to the relative proportions of which acid and alkaline reactions are due. To these ions, for instance, the heart, the respiratory centre, and many enzymes are extraordinarily sensitive. The heart of the frog is killed by a change in reaction as small as that which would be produced in a litre of distilled water by the addition of 0·036 mgm. of hydrochloric acid. Protoplasm must be approximately neutral (it is perhaps generally very faintly alkaline), and in ordinary circumstances it maintains its neutrality by a remarkable provision. Any acid which enters or is produced in the organism is used up in

turning monohydrogen phosphate into the neutral salt (as Na_2HPO_4 into NaH_2PO_4) and bicarbonates into carbonic acid (as $NaHCO_3$ into H_2CO_3). Alkalis are used up in effecting the reverse changes. Since both di- and mono-hydrogen phosphates, and bicarbonates and carbonic acid are only feebly acid or basic (feebly dissociated into ions), the result is to neutralize the acid or alkali.[1] Animals tend to increase the acidity of water they are living in, by the carbonic acid they produce. Plants tend to lower acidity by removing carbonic acid. Sea water is slightly alkaline, fresh waters often slightly acid.

The sensitiveness of animals to salts is well seen in the experiments of Herbst, Loeb, and others upon the development of sea-urchins, and upon other naked marine organisms. It has been found that for the normal life and development of such organisms there is necessary not only a certain concentration, but also a certain qualitative composition of the watery medium in which they are living. Thus for sea-urchin eggs there must be present the kations of sodium, potassium, magnesium, and calcium, and the anions of hydrochloric, sulphuric, and carbonic (HCO_3) acids, and a slight excess of hydroxyl over hydrogen ions (*i.e.* slight alkalinity). Similar results have been obtained for larvæ, and for the adults of jelly-fish, flatworms, etc. It appears that the composition which is most favourable is different for different animals; that a salt which ordinarily is harmless may become injurious in the absence of certain others which normally are present as marine animals will not live in a solution of common salt of the same osmotic pressure as sea water, but will tolerate it if calcium and potassium chlorides be present—and that the reaction of the water is of great importance.

Differences in the saline contents of water which are not actually harmful to an animal may nevertheless affect its growth so as to alter its bodily form, as may be seen in the well-known case of the Brine Shrimp (*Artemia*).[2] A similar direct effect of the reaction of the water is shown in the growth of long spicules on the surface of certain calcareous sponges when, by overcrowding, the medium becomes slightly acid. An animal is said to be *euryhaline* when it can live in waters which differ considerably from one another in salinity, and *stenohaline* when it cannot. Stenohaline animals may need a high salinity, as do the Echinodermata, or, like the Amphibia, require it to be low.

A remarkable feature of the action upon organisms of salts dissolved in the medium is the great effect which is sometimes

[1] This is known as "buffer" action. [2] See p. 260.

exercised by very small quantities of a solute. This is well seen in the poisonous qualities of ordinary distilled water. Water distilled in glass vessels is harmless, but if, as usually, it has been in contact with metals, it takes up minute quantities of these as hydroxide or carbonate, and it is then exceedingly injurious—as, for instance, it has been found to kill tadpoles and waterworms. On the other hand, small aquatic organisms

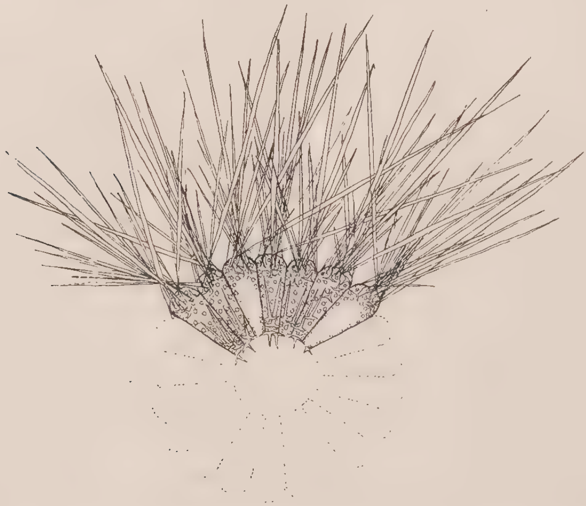


FIG. 220.—Part of a transverse section of a specimen of *Sycon*, growing in an aquarium.—After a drawing by Dr. G. P. Bidder.

are able to make use of exceedingly minute quantities of materials dissolved in the water in which they are living. Thus phosphates are extraordinarily dilute in sea water, but organisms collect them in large quantities ; and certain radiolarians construct skeletons of strontium sulphate, using for the purpose the very small trace of strontium present in the sea. This, however, is perhaps less remarkable than the case of the poisoned tadpoles, because, owing to their small size, the animals present a relatively large active surface to the water. (*e*) The injurious substances that may be carried by water are not only inorganic. Poisonous products of the life and decay of organisms are also liable to be absorbed from it by the unprotected surfaces of animals, and especially by those of their respiratory organs.

There are other differences between water and air, regarded as media for animal life, in which water has no advantage or is

even disadvantageous. (vii) Since water is heavier than air, it has greater *inertia*. It has also a moderate degree of *viscosity*. In virtue of these properties it is harder to cause to flow, or to resist when it is in motion, or to travel against. (*a*) This must be set against the saving of energy which its support affords to swimming animals. (*b*) Wave motion is for the same reason a serious matter for water animals with delicate bodies, as is seen in the stout armour and clinging or sheltering habits of such dwellers on a surf-beaten shore as limpets, acorn-barnacles, and certain crabs, and the way in which many members of the surface fauna sink in bad weather to safer depths. (*c*) It is probably partly on this account[1] that organs which are used for breathing when water is the medium have different modes of renewing it over the respiratory surface from that which is adopted in air. While air is drawn in and out of spaces with dead ends, by reversal of the current, as in the lungs of vertebrates, snails, scorpions, and spiders, and the tracheæ of insects, spiders, etc., animals that breathe water generally cause it to pass in a continuous stream over their gills, as do fishes, most molluscs, and decapod crustaceans, or move the gills to and fro in it, as other crustaceans. (viii) Whereas the *proportions of the gases* of air remain very constant everywhere except where large numbers of animals are breathing it in a confined space, which rarely happens in Nature, those of the gases dissolved in water vary greatly. (*a*) Though the absolute amount of free *oxygen* which can be dissolved in a given volume of water is much less than that which is contained in the same volume of air, yet since it is more soluble than nitrogen its proportion to that gas is higher (about 34 per cent.) in the gases dissolved in water than in air. The amount of these, however, varies with various circumstances, among others with the temperature. Near the Antarctic it may be as much as 24 c.c. per litre ; in the tropical Pacific it has been found as low as 12 c.c. per litre. It does not vary greatly with depth in the open ocean, but in enclosed seas like the Black Sea, and at the bottom of fresh waters, decomposition of organic matter may remove the free oxygen altogether. Animals, however, can stand a considerable diminution of oxygen in the medium they breathe ; and when it falls very low or vanishes, the scavenging fauna (p. 11) which inhabits such localities exists by the "anaerobic" mode of life, found also in many internal parasites, in which energy is obtained by a remarkable process of decomposition of the complex molecules of carbohydrates to form simpler ones

[1] Though partly on account of the more rapid diffusion of gases in air, which renders stagnant portions of it less harmful.

and set free energy without the intervention of free oxygen. The carbohydrate appears to be dextrose or lævulose. In the parasitic round-worm *Ascaris* the reaction is said to proceed as follows :

$$\underset{\text{Dextrose.}}{4\ C_6H_{12}O_6} = 9\ CO_2 + 9\ H_2 + \underset{\text{Valerianic acid.}}{3\ C_4H_9COOH}$$

The dextrose is stored in the form of glycogen, which is often extraordinarily plentiful in the tissues of anaerobic animals, such as internal parasites and the inhabitants of putrefying substances. Nearly half the weight of a tapeworm has been found to consist of this substance. It has been shown that many protozoa, worms, freshwater insects, etc., can live for a long time without oxygen. (*b*) *Carbon dioxide* also varies greatly with the presence of animals and putrefying matter. In small quantities it is not injurious, but gives the slightly acid reaction that is favourable to some freshwater animals. In large quantities it acts fatally, as a narcotic. It is less harmful in the presence of oxygen, but the circumstances in which it is formed, in Nature, are such that where it is plentiful oxygen is usually lacking. (*c*) *Sulphuretted hydrogen* is present where putrefaction is going on. In sufficient quantity it is poisonous, and by removing oxygen it is harmful in another way. Together with other properties of water, such as its lower mobility, these qualities result, as will be shown in a later chapter (p. 249), in a decided inferiority of the liquid medium to the gaseous for respiration. (ix) The *transparency* of water is one of the properties that make it a good medium for living beings, but, of course, vision is less easy in it than in air. The extreme depth to which sunlight can penetrate in pure water appears to be a little over 600 fathoms, but long before that it has become exceedingly feeble. Heat rays are absorbed before those of light, and the red rays penetrate less far than the blue. If the water contain suspended matter, either as mud or as the bodies of organisms, the penetration of light is reduced. It would probably be correct to take 100 fathoms as the depth beyond which, on the average, light has practically no effect upon any organisms except animals with peculiarly developed eyes. (x) Water exerts a greater *pressure* upon its inhabitants than does air; but, as we have seen, this is only occasionally a matter of importance. (xi) Lastly, a difference which depends only indirectly upon the essential properties of water and air, but which nevertheless exists between the layers of these media which cover the sea and river bottoms and dry land, is that the *currents* of the air are with some exceptions much less constant than those of the water, and

therefore affect much less the organisms which are subjected to them. Only in certain islands do they so tend to sweep away animals which leave the ground that flight is restricted or impossible.

Concerning characteristic features of the water fauna as a whole, there is not very much that can profitably be said. Its members live in so great a variety of circumstances and have been so often recruited from the land that no generalization can be applied to them all. It is, on the whole, stenothermal, and only accidentally contains warm-blooded members. Its protoplasm is often exposed without shelter or cuticle to the medium. Its tissues are more delicate and supported by slighter skeletons than those of land animals. It has often swimming organs or apparatus for increasing its buoyancy. It is frequently sessile. It usually exchanges the gases of respiration with water, and often has organs adapted to that function, which they perform either by merely exposing the respiratory surface to the water, by moving it in the water, or by drawing the water in a continuous stream over it. Frequently the gametes or oösperm are set free to float in the medium.[1]

[1] This paragraph refers mainly to the primary water fauna. About the secondary fauna of the water, which consists of animals living in it but derived from a land stock, something is said on p. 253.

CHAPTER VIII

THE FAUNA OF THE SEA

Two principal divisions may be recognized in the water fauna—those of the sea and of fresh waters. The sea is the great reservoir of the waters of the globe and has existed as such continuously from the earliest geological times, often altering its outline but never substantially losing its continuity. From it the fresh waters are distilled by the sun's rays and sprinkled upon the surface of the land, where they trickle back to the sea by channels which are continually altering, and rarely permit them to attain to any great depth, but subject them in comparatively shallow layers to the light and heat of the sun or the cooling effect of radiation and evaporation into air. As they run, they take up from the land salts of various kinds, differing with the rocks upon which the waters have fallen, and bear them to the sea. There the salts accumulate, while the waters, constantly redistilled, repeat their journey. It is clear that the conditions of life for animals which inhabit the waters in these two very different parts of their circuit will be correspondingly unlike; and we may expect that to some extent they will be reflected in differences in the faunas.

1. There are, of course, between the sea and fresh waters great differences in *salinity*. (*a*) The difference in the *amount* of salts in solution is well known. On the average the saline contents of sea water are 35 parts per 1000; those of fresh waters are on the average 0·18 parts per 1000. (*b*) In *composition* the salt content of fresh waters is very different from that of the sea. In sea water the percentages of its principal component bases and acid radicles is as follows:

Na	30·64
Mg	3·76
Ca	1·20
K	1·09
Cl	55·21
SO_4	7·70
CO_3	0·21
Br	0·19

The salts dissolved in fresh water vary greatly with the rocks over which it has passed, but they are principally carbonates (on the average 57·7 per cent.), sulphates (11·4 per cent.), and silicates (9·9 per cent.). Chlorides are scanty, common salt, the most plentiful, being only 2·2 per cent. Broadly speaking, the great differences between the two kinds of waters are the much greater proportion of sodium chloride in sea water and of calcium carbonate (usually) in fresh waters, and the relative poverty of the sea in silica.[1] (c) The salt content of fresh water *varies* much more than that of the sea. In the latter, thanks to the currents which set through it in various directions, the salinity is remarkably constant. (i) Its constancy, however, is more marked in its *composition* than in its concentration, probably because, by rainfall and by evaporation, the latter is more quickly changed in various localities. But the waters near land, just above the bottom, and in frozen seas, where the ice takes up more of some salts than of others, show slight differences from those of the open ocean. (ii) In *concentration* sea waters differ more considerably. As has already been stated, the average amount of salts present is 35 parts per 1000, but where there is much evaporation and little rainfall it is higher, and where there is heavy rainfall, or much river water enters the sea, or melting ice adds fresh water, it is lower. It is highest in the Eastern Mediterranean and in the Red Sea, where it is over 39 parts per 1000, and also very high (over 36 parts per 1000) in the subtropical parts of the great oceans, at a distance from land. It is lowest (20 parts, or less, per 1000) in the Baltic and Black Seas, and also low (32 parts per 1000) in the extreme north of the Atlantic and Pacific and in the Arctic Ocean. These differences, however, are but slight in comparison with those which exist between fresh waters, which in rivers that flow over granite rocks may contain as little as 0·03 parts per 1000, while those which have traversed limestone may rise to 0·73 parts per 1000. In view of the importance which, as we have seen, the saline contents of waters have for the animals that dwell in them, it is not a little remarkable that few if any peculiarities connected with this factor are found to distinguish the marine and

[1] These differences show that the salts of the sea are not merely accumulated by the concentration of river water, but that some of them are removed by certain agencies. Carbonate of lime is withdrawn to form shells and coral, and after the death of the organisms which do this only a part is returned by re-solution. Silica is withdrawn to form the skeletons of sponges and radiolarians and the shells of diatoms. Potassium salts combine with silicates of aluminium to form glauconite in the presence of organic matter. Sodium and chlorine are not withdrawn, but accumulate, to give sea water its large percentage of common salt.

freshwater faunas, taking each as a whole. Indeed, it is a striking fact that sessile animals with calcareous skeletons, such as corals, calcareous sponges, and polyzoa with calcified cuticle, are numerous in the sea but almost absent from fresh waters, which are often far richer in calcareous salts. Most marine animals are killed by being transferred to fresh water, and so are freshwater animals when they are placed in sea water; but there are some (salmon, eels, etc.) which regularly migrate from one to the other, and others, such as plaice, sticklebacks, various freshwater mussels and snails, and the hydroid polyp *Cordylophora*, do so occasionally; while it has been found possible, by gradually changing the salinity of the water, to accustom many members of each of these faunas to the habitat of the other.

2. The *temperature* of the sea is less variable than that of fresh waters. It is true that sea water has less capacity for heat than fresh, and its temperature tends to alter more quickly on this account; but, on the other hand, most of it lies beyond the influence of the daily and seasonal alternations of heating by the sun and cooling by the air, and almost everywhere under the surface layer there is a mass, such as is only found in deep lakes, which by convection moderates its changes, and also affords a refuge for its fauna.

Nevertheless the variations of the temperature of the sea are far from being negligible. Near the surface the temperature varies both from place to place and from time to time. It varies also vertically; and in the deeper layers there is some variation from place to place, though none from time to time. (*a*) The surface temperature varies, roughly speaking, with latitude, though it is also influenced by other factors, notably by currents and by the neighbourhood of land. In a broad belt along the equator its annual mean exceeds 80° F.[1] Between 40° S. and 40° N., and beyond that latitude in the North Atlantic, it exceeds 60° F. It is 40° F. at 55° S. and at about the same distance to the north of the equator, except in the North Atlantic, where that temperature extends to 70° N. (*b*) The surface temperature also undergoes daily and annual variations. The daily variation is but slight: probably nowhere in the open ocean is its mean above a degree Fahrenheit. The annual variation differs much in different parts of the globe. In the Tropics, and in the Arctic and Antarctic, it does not exceed 10° F. In the temperate zones it is usually from 10° F. to 20° F.,

[1] Temperatures are here given in Fahrenheit degrees, in which they are stated in the classical *Challenger Reports* and in many other works on the subject.

but in places—notably in belts across the North Atlantic and North Pacific—it is greater. In the North-west Pacific and North-west Atlantic, where cold currents prevail at one time of year and warm at another, it is very great, at times exceeding 50° F. The greatest annual variation that has been recorded is 56° F., for an area in the North-west Atlantic. The lowest recorded surface temperature is 26° F., observed in the North-west Atlantic, and the highest 96° F. in the Persian Gulf. (*c*) The temperature varies also in successive layers from the surface downwards. Save in the Arctic and Antarctic and in some other exceptional localities, it decreases continuously to the bottom. This is shown in the following table of mean temperatures for the whole ocean, taken from the " Challenger " Report:

Depth in Fathoms.	Mean Temperature.
100	60·7° F.
200	50·1° F.
500	40·1° F.
1000	36·5° F.
1500	35·3° F.
2200	35·2° F.

The high surface temperature is, of course, due to the warmth of the sun's rays. It is believed that the low temperature at the bottom is due to a creep of cold water from the poles to the equator (except where it is held up by ridges of the sea floor, as will be explained shortly); and that the temperatures of the intermediate layers are due not only to conduction, but largely to the fact that the surface water which becomes warmed in the tropics sinks wherever by evaporation its salinity and so its density are increased (see p. 207), and mingles gradually with the cold water as it sinks. The actual temperatures are not arranged so simply as the table above might suggest, for the fall is sometimes more and sometimes less rapid than that of the mean temperatures. This is due principally to two causes. Ocean currents, caused largely by the winds, carry quantities of the warm surface water from one locality and accumulate it in another, where it warms the lower layers unduly. This happens, for instance, in the Atlantic, where the deeper waters are warmer in the northern part of the ocean than south of the equator. Again, where a ridge rises from the sea floor it is apt to alter the normal state of affairs. On one side of the ridge the usual gradient of temperature is found. On the other it ceases at the level of the crest of the ridge, and thence downward the temperature is constant. This is believed to be due to water tending to

flow from the normal side to the other and being held back by the ridge, so that what crosses is at the temperature proper to the level of the ridge-crest. Such conditions are found in the partly enclosed seas on the western side of the Pacific, such as the Celebes, Sulu, and Banda Seas, where the flow is inward to the basin, and again where the Wyville Thomson Ridge holds back the cold bottom waters of the Norwegian Sea from the Atlantic, and in the Mediterranean and Red Seas, where the warm water which accumulates within the barrier overflows it outwards. The actual bottom temperature varies with such circumstances and, of course, with depth; but at 2000 fathoms and over it is always very low, even under the equator, and may even be below the freezing point of pure water, as in the Arctic and Antarctic Oceans, where it reaches its lowest at 30° F. This is only possible because, owing to its salinity, sea water freezes at a lower point (28° F. for 35 parts of salts per 1000)

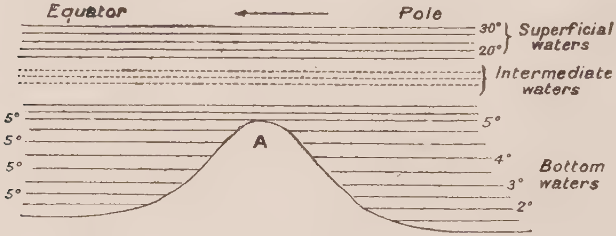


FIG. 221.—A diagram to illustrate the effect of a barrier (*A.*), at right angles to the direction of a polar current, upon the bottom temperature.—From Hickson.

than fresh water, and has its maximum density at the freezing point, not 7° F. above it as is that of fresh water. In fresh waters the bottom layers cannot fall below 39·2° F. until the whole is frozen, and they are thus often at a higher temperature than the surface. It will be seen, however, that, in spite of the cold bottom water, the vertical range of temperature in the sea is less than the horizontal. The equable climate of the seas is no doubt responsible for the fact that many of their inhabitants are highly stenothermal. When currents of warm and cold water meet, this causes a great mortality among their plankton and nekton ; and the bodies of these creatures, falling to the bottom, provide plentiful food for the benthos. In certain parts of the ocean, as where the warm Japan stream meets the cold Kamchatka current, the benthic fauna is unusually rich from this cause.

3. The *currents* of the sea are very different from those of fresh waters. (*a*) While they may attain a considerable swiftness they

never rush at the rate of a mountain torrent, and *their average speed is less* than that of the rivers. It is possible, therefore, for a larger proportion of the animals that are subjected to them to swim against them; and those that are borne with them may often live out a lifetime before they are brought into substantially different conditions. (*b*) Whereas in fresh waters, whatever lesser currents may be set up in lakes, ponds, etc., the main flow is always in one direction—the return to the sea—*marine currents set in many and various directions*, and not infrequently cease or reverse after short or long periods.

(*a*) In so far as it is possible to sum them up in a single phrase, the *great ocean currents may be said to constitute a circulation to and from the equator.* Thus, while the principal currents of fresh waters tend to bear their inhabitants to salt water, these of the sea carry members of its fauna either from warmth to colder conditions or in the reverse direction. The principal factors which bring about the circulation of the waters of the sea are the winds that play upon its surface and the variations in its density. (i) The direction of winds is determined by atmospheric pressure and by the rotation of the earth. Over the equator the hot air ascends, so that pressure is low. Farther north and south there are areas of high pressure which cause prevailing winds to blow outwards towards the equator and the poles. These winds, however, do not set due north and south because, on account of the shape of the globe, its spin turns each wind to its right in the northern hemisphere and to its left in the southern hemisphere. Thus the winds which flow towards the equator (trade winds) set south-west and north-west and converging drive the equatorial waters to the west; but the winds which blow towards the poles are south-west and north-west winds and set north-east and south-east and drive the waters in these directions. In the Southern Ocean, beyond the continents, the "brave west winds" of the "roaring forties" of latitude set round the world westward carrying the waters with them. The system of currents which results from these winds is as follows. In the warm tropical waters of each ocean an Equatorial Current flows on each side of the equator westwards. On reaching the eastern side of a continent it is deflected. Part of it turns equator-wards, where an Equatorial Counter-Current sets eastwards between the westward Equatorial Currents; but most of it turns away from the equator, northwards or southwards as the case may be, and joins the north-eastward or south-eastward currents caused by the set of the south-west or north-west prevailing winds of the temperate zones. Thus, the North Equatorial Current of the

Atlantic pours water into the Caribbean Sea, whence it issues as the Gulf Stream to join the North Atlantic Drift which flows north-eastwards to bathe our shores. Where one of these eastward

FIG. 222.—Ocean Surface Currents.

currents impinges upon the western side of a continent, part of it —now much cooler—is turned towards the equator again, and thus completes a circuit, in which the water travels in the direction of

the hands of a clock if it lie to the north of the equator, but counter-clockwise if it lie to the south. The rest of the eastward current escapes into the Arctic or Antarctic Ocean, from which also contingents are drawn into the circuit of each ocean, entering principally along the western side of the northern half of the ocean and along the eastern side of the southern half. The several currents are shown and their names given in Fig. 222. (ii) But besides this surface circulation from and to the equator there is a vertical one, in which warm water travels from the equator towards the poles at the surface and cold water from the poles to the equator at the bottom. In the causing of this, density plays its part. The variations in density are due to two causes—temperature and salinity. In the tropics, except where the rainfall is heavy, evaporation raises the salinity, and would thus raise the density were it not counteracted by the high temperature which tends to keep the water light. In the Arctic and Antarctic the low temperature tends to make the water heavy, except where it is counteracted by the melting of ice. We have seen that warm saline water is driven by south-west and north-west winds north-eastwards and south-eastwards towards the poles, and cools as it goes. Presently, being both salt and cool and therefore very heavy, it begins to sink below the proper polar waters, which though very cold are less saline. On reaching the bottom some of it flows towards the pole, but much returns to the equator as the creep of cold water which has already been mentioned. In the tropics it rises, warming as it goes, to take the place of the water there removed from the surface both by the currents we have described and also by evaporation. It is this cold water which carries down with it the atmospheric gases by which the deeper layers of the ocean are aerated. To complete the picture, it should be mentioned that the surface waters of the Mediterranean and Red Seas, heated and concentrated by African desert winds, sink to the bottom and thence flow out into the Atlantic and Indian Oceans, where they are recognizable as warm, salt layers at intermediate depths.

(β) Many of these currents, and of the innumerable lesser ones that are subsidiary to them, alter with the season, and some of them even cease during certain months, so that *the current in any locality may vary* with the time of year. Thus the North Equatorial and Equatorial Counter-Currents of the Indian Ocean are obliterated by the South-west Monsoon. There is, moreover, another class of currents, caused by the tides, that are reversible at intervals of a few hours. It must be largely due to these fluctuations and reversals of currents, though no doubt also to the leakage which

takes place at their edges into counter-currents, and to the backward eddies which they set up against promontories, that species which at any time of their lives are planktonic can maintain themselves in their habitats.

We have already noted (pp. 204 and 205) how the currents of the sea can affect its inhabitants by bearing them to regions where they meet unaccustomed conditions of temperature; but how, on the other hand, owing to their comparative slowness and inconstancy, they dominate the fauna less than those of fresh waters. This is clearly reflected in one difference that exists between freshwater and marine animals. An immense number of members of the benthos and nekton of the sea have floating eggs or larvæ or other phases of the life-history (such as the medusa) that by their feebleness or inability to swim belong to the plankton. In freshwater animals such stages are liable to be swept into the sea and are often suppressed. The contrasts between the life-histories of *Hydra* and marine hydroids, the Crayfish and the Lobster, and the Freshwater Mussels and Sea Mussels, well illustrate this.

4. In *area* and *depth* the contrast between the sea and the fresh waters of the globe is, of course, very great. Taken as a whole, the fresh waters have perhaps a volume of 150,000 cubic miles. Their area is about 1,000,000 square miles. The greatest of them, Lake Superior, has a volume of 2900 cubic miles, and an area of 31,200 square miles. The maximum depth of the deepest lake, Lake Baikal, is said to be about 900 fathoms. The volume of the sea, on the other hand, is 324,000,000 cubic miles, its area 140,000,000 square miles, and its greatest known depth, which it reaches in the Swire Deep, off Mindanao, 5438 fathoms (that is, 6 miles 136 yards). Murray gives the following figures for the areas of the ocean which lie at various depths:

Depth.	Percentage of Total Ocean Floor.
Between 0 and 1000 fathoms.	16
,, 1000 and 2000 ,,	19
,, 2000 and 3000 ,,	58
,, 3000 and 4000 ,,	7
Exceeding 4000 ,,	less than 1

Depths of 5000 fathoms are very rare, and only known in the Pacific. The mean depth of the ocean is 2080 fathoms. Around the edge of each continent there extends a *continental shelf*, sloping gradually to about 100 fathoms,[1] for an average distance of 50 miles

[1] These figures are, of course, only very rough approximations.

from the coast. From this the sea bottom falls, rapidly at first and then more gradually, as the *continental slope*, to some 2000 fathoms, at which it reaches the *abyssal plain*, and here it again slopes gently over wide areas to greater depths. From the abyssal plain there stand up in places mountains, which may reach the surface as islands, and in places deep pits sink to 4000 fathoms or more, but in the greater part of its extent it shows only very gentle undulations.

We have already noted that restriction of the space in which the life of an animal is passed, such as is common in fresh waters, may have consequences both for the individual and for the race.

5. The *drying up* or *freezing through* of their habitat is not a danger that attends marine animals as it does those that live in the smaller pieces of fresh water.

6. On the other hand, *tides* are a feature of the sea that is of great importance for many of its inhabitants, but not for those of fresh waters. Besides causing the currents that have been mentioned, they expose a number of animals for several hours of the day to very adverse circumstances—great changes of temperature, collapse of gills and other delicate organs through lack of the support of the water, the exchange of gases with the air, for which most of them are not organized, lack of food, the danger of drying up, pursuit by land animals, violent wave action, drenching with fresh water, etc. Only the hardiest members of the fauna—eurythermal, euryhaline, strongly built, and able to cling firmly to, or to burrow in, their substratum—can stand these conditions.

7. The *viscosity* of sea water is greater than that of fresh water. This property, however, is perhaps of less importance as a standing difference in the conditions of life than as a varying factor in the surroundings of water animals. It alters with the salinity, but undergoes greater variations as a result of changes in temperature, and thus affects, for instance, the rate at which the plankton tends to sink, which it makes greater in summer and in warm climates than in winter and in cold climates.

8. The inorganic *suspended matter*, and that portion of the organic matter which is of land origin, are, as a rule, less in sea water than in fresh water. This is due to two causes. Most parts of the ocean are beyond the reach of the suspended matter which it receives from the land, whereas, owing to the smaller size of pieces of fresh water, this is not true of them; and the saltness of the sea, by a physical action, brings about the deposition of such matter more rapidly than it takes place in fresh waters. In all waters, turbidity naturally depends largely upon the nature of the

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rocks from which they are supplied. Turbidity is of importance by affecting the translucency of the water, its tendency to smother the benthos by depositing sediment, etc. The total suspended matter depends, of course, partly upon the amount of the plankton; and since this is a very important source of food for the whole fauna, the presence of matter in suspension is not always prejudicial to the benthos.

Some general characters of the marine fauna will have been gathered from the foregoing pages. The majority of its members are stenothermal,[1] do not thrive in water of low salinity, are distributed by larvæ or other planktonic stages, and do not form drought- or cold-resisting cysts or egg shells. Many of them have a strong, calcareous cuticle, shell, or coral. Besides these features of its members, the marine fauna is remarkable as a whole for its richness and variety. That it should be *rich* by mere numbers is understandable, since a region with a water medium is, for reasons that we have already seen, more favourable to life than the land, and in temperature, in salinity, in the nature of its currents, and in permanence the sea offers more equable conditions than fresh waters. Its *variety* may perhaps partly result from the strenuousness of competition and chances of variation which exist where numbers are high, but is no doubt mainly due to the fact that it is the oldest of the faunas.

Life almost certainly started in the sea. That it offers the most favourable conditions makes this probable; and the earliest organisms that geology has discovered were marine. An interesting indication of the marine origin of animals is afforded by the fact that the saline contents of the blood-serum of non-marine vertebrates are substantially those of sea water. Sodium, potassium, and calcium are present in similar, though not identical, proportions in the two fluids, and there is the same preponderance of sodium chloride. The most important differences are the higher salinity of sea water, and the considerable proportion of magnesium which it contains. It has been inferred from these facts that the composition of the blood was fixed during a long ancestry in sea water, by the protoplasm, which was at first exposed to the water, setting up habits of metabolism which required that the fluid which bathed it should have the composition which sea water then had; and that this composition was of necessity maintained by those vertebrates which forsook their original habitat. Since the salinity of the sea grows gradually by the accumulation of salts in the way we have

[1] Animals which live between tide marks, especially in the tropics, are eurythermal.

seen (p. 200), it is probable that in the Cambrian period, when the Vertebrata arose and their constitution became fixed, the ocean was less salt than it is now, and there is also reason to believe that the Cambrian ocean was less rich in magnesium than that of to-day.

As it started in the sea, so life long continued there before it began to invade the rest of the globe. All the lowest and earliest established groups of animals are essentially marine, though representatives of many of them have wandered into fresh water and constitute the majority of its inhabitants. Protozoa are numerous in both the water faunas, but sponges and cœlenterates are rare in fresh waters, and echinoderms are purely marine. Worms, crustaceans, molluscs, and fishes took origin in the sea, though they are now numerous in fresh waters and a few of them have reached land. Only the air-breathing arthropods and vertebrates are essentially land animals, and even they have sent back representatives to the sea. In short, there is no important division of the animal kingdom which has not some marine members, and many are almost or quite confined to it.[1]

[1] A fuller list of the groups of aquatic animals that do not occur in fresh waters will be found on pp. 252, 253.

CHAPTER IX

FOOD AND SUBFAUNAS IN THE SEA

SEA and Land are on the whole independent in the matter of food supply. Save in so far as Man disturbs the balance of nature by bringing organisms from sea to land to serve for food, either directly or indirectly as manure, the amount of organic matter or salts that the land receives from the sea is insignificant, and most of that either decays uselessly upon the beach where it has been cast up, or accumulates as guano in the homes of sea birds where there is no vegetation for it to fertilize. It is true, on the other hand, that a large quantity[1] of nitrate plant-food is yearly borne into the sea by rivers into which it has been washed by the rain, and with it a less quantity of organic remains, and that this is an important item in the economy of coastal waters; but it is not even there the sole source of supply, and its influence does not extend very far to seaward.

In the sea, as on land, the food of animals is provided, in the long run, by plants. The plants of the sea belong to the following classes:

1. *Flowering plants* are very few. The Eel Grass (*Zostera marina*), common in the Atlantic in sheltered places with a muddy bottom, is the best known. All are rooted to one spot.

2. *Fixed seaweeds* are found on almost all coasts. They may belong to the Green Algæ, as *Ulva*, the Sea Lettuce; to the Red Algæ, as the Carrageen or Irish Moss (*Chondrus*), and the Coralline Seaweeds or Nullipores, such as *Lithothamnium*, with strongly calcified cell-walls, which are plentiful at moderate depths in our waters, and in the tropics form a great part of many coral reefs; or to the Brown Algæ, which are the most numerous. Of these *Fucus*, the Wrack, is found up to high-water mark. *Laminaria*, the Oar-weed, begins at low-water mark. *Macrocystis* is an immense laminarian found in the Southern Ocean. It may reach a length of 800 feet. *Sargassum*, the Sargasso Weed, grows on the coasts of the West Indies

[1] It has been estimated that 38 million tons of nitrogen are annually carried down to the ocean by rivers.

and Central America. It is torn away by the waves and carried by currents to the quiet region, known as the Sargasso Sea, which

FIG. 223.—The Narrow Ulva (*U. ulinza*).

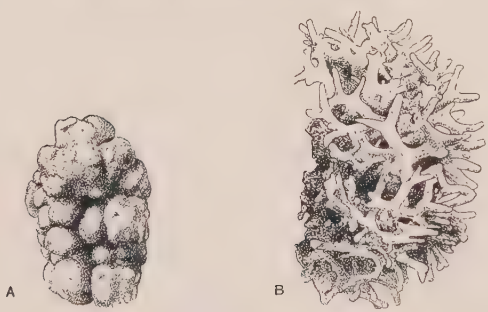

FIG. 224.—Coralline algæ.—From Weber van Bosse.
A., *Archæolithothamnium*; *B.*, *Lithophyllum.*

lies in the midst of the North Atlantic circulation. There it gathers in immense masses and floats, by means of the bladders

which, like the Bladder Wrack, it possesses, until it dies and sinks. Its floating masses are the home of a whole fauna of fishes, crabs, prawns, molluscs, etc., remarkably resembling it in colouring, which belong to coastwise groups of animals and are not related to the high seas plankton around them. For some reason, living seaweeds are food for few animals; but their remains feed a larger number.

FIG. 225.—The Toothed Wrack (*Fucus serratus*).

3. *Floating algæ*, using the term in its widest sense, are the most important marine plants, regarded as a source of food for animals. They are all small, and most of them are microscopic, but they are found in immense numbers and in every part of the sea to which light reaches. They include diatoms, some of which are fixed; dinoflagellates (*Peridineæ*), cryptomonads (free *Zooxanthellæ* and *Zoochlorellæ*); Coccolithophoridæ, which secrete the calcareous

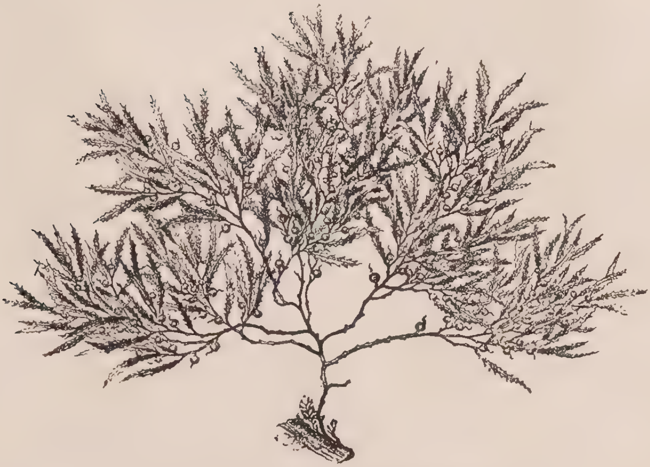

FIG. 226.—Gulf Weed (*Sargassum*).

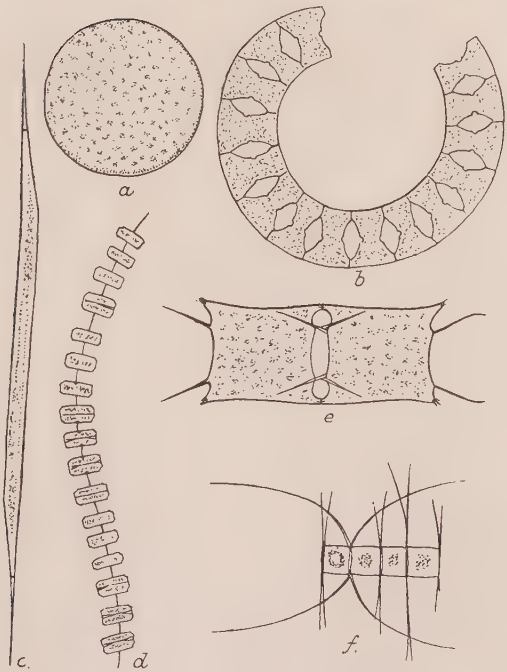

FIG. 227.—Diatoms of the Plankton.

a., Coccinodiscus; *b., Eucampia*; *c., Rhizosolenia*; *d., Thalassosira*; *e., Biddulphia*; *f., Chætoceros.*

structures known as "coccoliths" and "rhabdoliths" found in deep sea deposits; silicoflagellates; the green alga *Halosphæra*; and blue-green algæ (*Cyanophyeœ*). Most of them are not green, but brown or yellow. The most important of them are the Diatoms and Dinoflagellates. The flagellates among them are often regarded as animals, but functionally, as food-makers, they are plants. Not only do they serve as food to the fauna at the level in the water at which they live, but when they and the animals which there feed upon them die and sink they supply the ocean throughout its depth (p. 190).

4. *Bacteria* are found everywhere in the sea, as they are on land and in fresh waters. Some of them reveal their presence by pro-

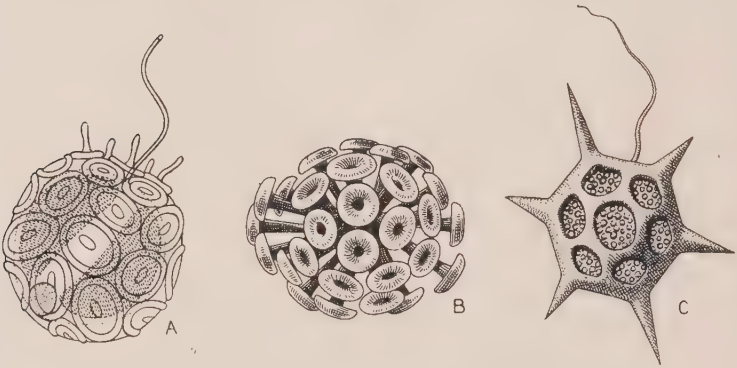

FIG. 228.—Minute plants of the sea-surface.
A., *Syracasphæra pulchra* (Coccolithophoridæ); *B.*, the shell of *Discosphæra tubifer* (Coccolithophoridæ); *C.*, *Distephanus speculum* (Silicoflagellata).

ducing light, and are among the causes of the phosphorescence of seas. As we have seen (p. 10), though they are not food producers for animals, many of them play important parts in preparing the excreta and dead bodies of other organisms to form food for plants. In so doing, however, some of them produce poisonous products, of which sulphuretted hydrogen is perhaps the most injurious to the fauna of the sea. Other bacteria, such as *Beggiatoa*, lessen the amount of sulphuretted hydrogen by oxidizing it. Lastly, certain of them are of very great importance in the economy of the sea in quite a different way. In water, as on land, there are genera (*Azotobacter* and *Clostridium*) which have the power of fixing free nitrogen from the air—in this case dissolved in the water—and thus they form nitrates. By this very remarkable habit, which is possessed by no other organism and can only be imitated by man with the

expenditure of much energy, they make the sea self-sufficient in the matter of food ; for without their aid plants, which cannot live

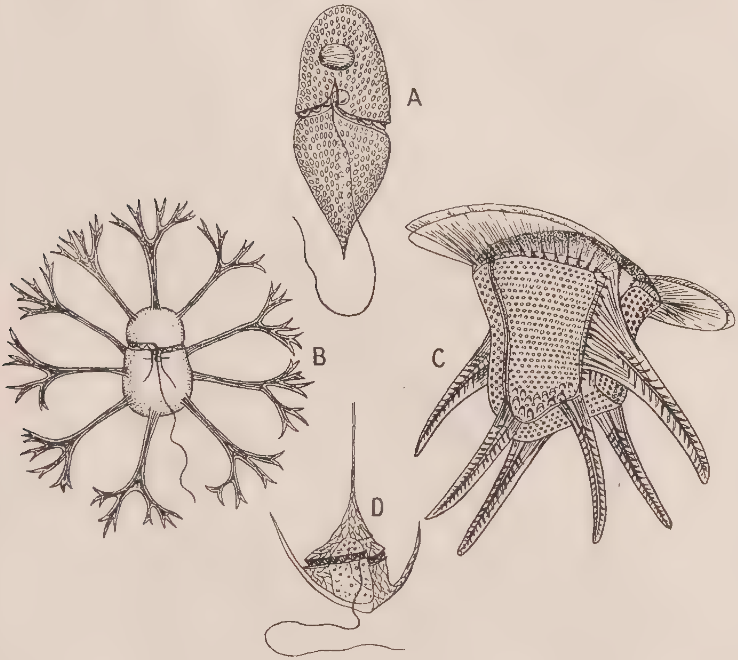

FIG. 229.—Dinoflagellates of the sea-surface.—After various authors.

A., Gymnodinium fuscum ; B., Cladopyxis brachiolatum ; C., Ceratocorys horrida ; D., Ceratium tripos.

without a supply of combined nitrogen, would presently be starved. That would happen because the circulation of nitrogen, which we

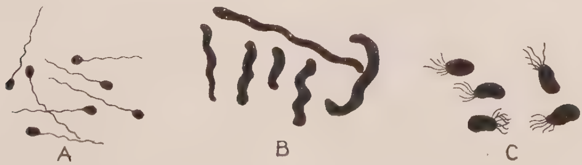

FIG. 230.—Bacteria of the sea-surface.—After Johnstone.

A., Nitrosomonas, which oxidizes ammonia to nitrous acid ; *B., Photobacillus*, a phosphorescent bacterium ; *C., Azotobacter*, a nitrogen fixer.

have seen (p. 11) to take place through the bodies of organisms, does not go on without loss. While the nitrogen in the form of nitrates

and other simple compounds is passing from the bodies of animals to those of plants, a certain amount of it is set free by species of *Bacterium* which in their life-chemistry break up the compounds in which it is contained. The amount of life in any part of the ocean probably very largely depends upon the balance between nitrogen-fixing and denitrifying bacteria.

The vast area of the ocean contains many faunas. These have been classified in various ways. Though it is not in any case possible to draw hard-and-fast distinctions between them, the difference is probably sharpest between the faunas of the bottom

FIG. 231.—Stalked barnacles upon driftwood, with the cirri in the act of gathering in food from the water by their clenching movement.

and those which are "pelagic"—that is, are not under the influence, direct or indirect, of a common substratum. The pelagic faunas consist of nekton and plankton only, though they possess an element, which we may call the "pseudobenthos," which is in relation with the surfaces of solid bodies, such as driftwood and the bodies of other organisms and in quiet waters with the surface film (p. 191). Bottom faunas contain benthos, nekton, and plankton, for in the layer of water immediately above the bottom there are swimming and drifting animals which feed on or serve as food for the benthos, and in this and other ways form a complex with it, though they are transitional to the pelagic fauna.

Among the *Bottom faunas* we may distinguish between those of the Photic Zone and the Aphotic Zone or Deep Sea. The latter may be again divided into the Intermediate Zone and the Abyssal Zone. The conditions of life which distinguish these zones depend upon the depths to which light, heat, movements of the water, falling materials, etc., penetrate from the surface. They are therefore limited by depth, and the limits (i) vary from place to place with circumstances, such as the amount of sunlight; (ii) are indefinite, the zones passing gradually, often very gradually, into one another. (iii) Further, like all limits between faunas, they are

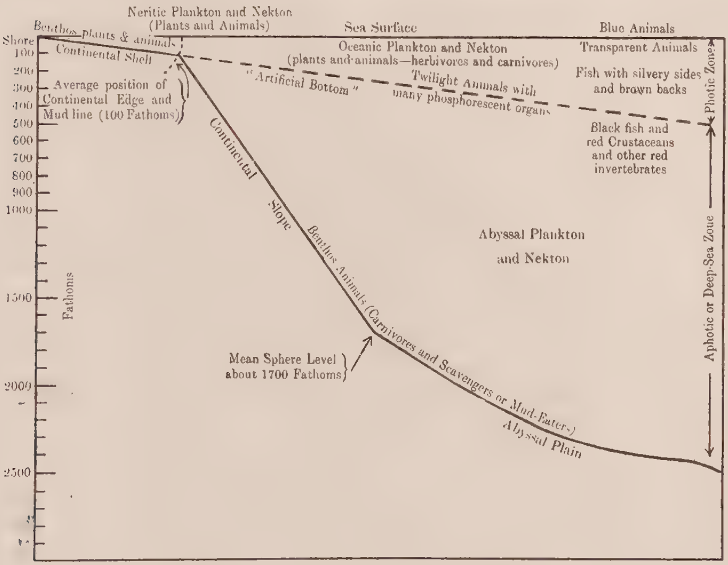

FIG. 232.—A diagram of the Zones of the Sea.—After Murray.

transgressed by species which are capable of doing so. Thus, inhabitants of the photic zone of northern seas, where its waters are cold, often range into the cold waters of the deep sea, even in latitudes in which the photic zone is too warm for them. The mollusc *Pecten grœnlandicus* extends from 5 to 1785 fathoms, *Arca glacialis* from 25 to 1620 fathoms, and *Natica grœnlandica* from 2 to 1290 fathoms. The hermit crab *Parapagurus abyssorum*, widespread at depths of 700 to 2000 fathoms, comes up to 45 fathoms in Patagonia. The same thing sometimes happens even where there is a difference in the temperature of the waters. *Scalaria hellenica* extends from 40 to 1260 fathoms in the Canaries, and the prawn

Nematocarcinus proximatus found in deep water (to 1800 fathoms) in various parts of the Pacific and Southern Oceans is reported from 28 fathoms in the Arafura Sea. But these are exceptional cases, and as a whole the faunas of the several zones are very distinct.

The *Photic Zone* is the region in which there is a considerable amount of light. Roughly speaking, we may take it as coinciding with the continental shelf and comprising the region over which the depth of the water is not more than 100 fathoms. Approximately at that level several changes take place in the conditions of life. Light is becoming very feeble and losing the last of its red rays ; the limit of wave action and strong currents is reached, and in consequence the finer matter brought down by the rivers in suspension is

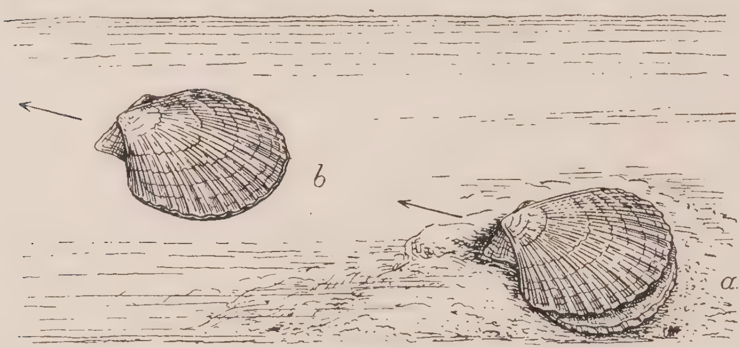

FIG. 233.—The Scallop (*Pecten*) in two positions of swimming.—From Pettigrew.

a., With valves parted in the non-effective stroke ; *b.*, with valves brought together in the effective stroke. The arrows show the direction of advance.

deposited as mud, so that the belt known as the " mud belt " begins; and the warmer surface water gives way to the deeper cold layer, so that the viscosity is greater. All these things, of course, happen at different depths in different localities, and in particular at a lower level in clear waters and in the tropics, where light and heat penetrate deeper than where there is much matter in suspension or sunlight is less, so that the extension of the photic zone is far from being everywhere the same. In the photic zone the waters are in more active and varied motion than below it ; the bottom varies from rock to mud, but is usually coarser in grain than that of the deeper regions ; salinity, viscosity, and temperature vary ; light is present ; and seaweeds grow. Thus the conditions are both different from and more varied than those of any other region of the sea. The fauna is correspondingly varied, and includes members of

every group of animals except those which, like whales and radiolarians, are specifically adapted to pelagic life on the high seas. The photic zone is divided into *littoral* and *sublittoral* zones. The *littoral zone* extends from high-water mark to a depth of about 20 fathoms, and is, of course, better lighted and more subject to movements and temperature changes of the water than the sublittoral. In it again a zone below low-water mark may be distinguished from

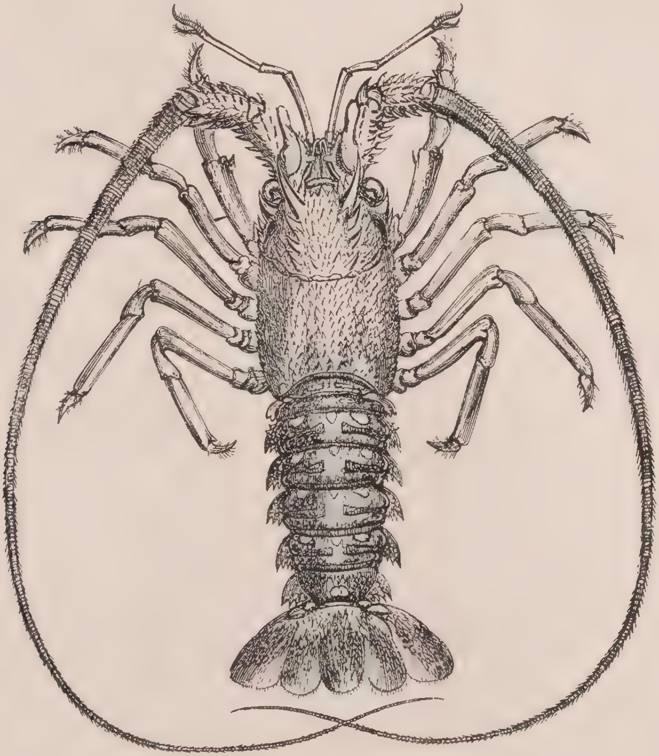

FIG. 234.—The Crawfish or Spiny Lobster (*Palinurus vulgaris*).

that between tide marks in which the fauna is subjected to the influences that we have noted on p. 209. Each of them is again subdivisible into belts and areas, but these differ on different coasts. Round our own island, for instance, there may be distinguished in the tidal zone of rocky localities a barnacle belt and a wrack or *Fucus* belt; and below these a laminarian belt extends to the sublittoral zone. Areas of rocky, shingly, sandy, or muddy beds of Sea Grass (*Zostera*), etc., diversify these belts, and every such type

of locality (facies) has its own fauna, as, for instance, a sandy bottom is rich in burrowing forms, and a rocky one in sessile animals, with all the creatures that shelter upon them. In the tropics, the littoral zone has, as a rule, a wonderfully rich and beautiful fauna (Frontispiece), and is often the site of a luxuriant growth of madrepores and other cœlenterates by which, when the conditions are suitable, reefs are formed (Fig. 128). Reef-building organisms do not grow below some 30 fathoms. The reefs, which are often composed in great part of coralline algæ, spread outward upon a foundation made by

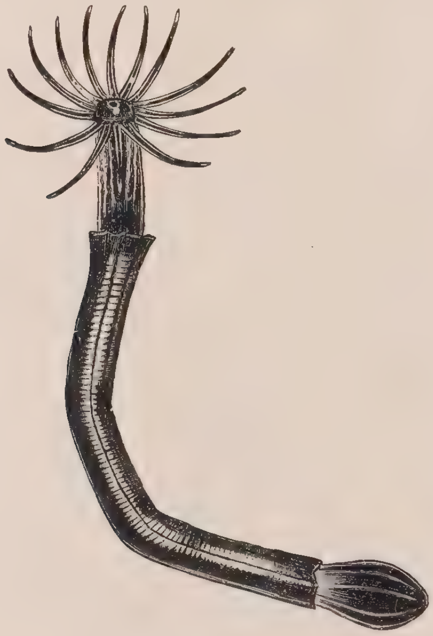

FIG. 235.—*Edwardsia beautempsi.*—From Hickson.

their own débris, broken off by the waves and rolled down the seaward slope. Meanwhile their inner part disappears, as the reef-builders die out, owing to their distance from the ocean waters, which bring food and oxygen and wash away the fine sand that is apt to smother the polyps. The dead growths, unprotected by living ones above them, are disintegrated by boring organisms and dissolved. Thus the fringing reef becomes separated by a channel from the land. The mode of origin of the ring-shaped reefs or atolls has been the subject of much dispute, some authorities holding, with Darwin, that each is due to the subsidence of an

island around which it was formed, others that they have grown up from submarine banks, and owe the lagoons within them to the same factors which form the channel within a fringing reef. Coral reefs are found only within 28° on each side of the equator, and for some reason are lacking on the western sides of the African and American continents. It is with the littoral zone that we must classify that fauna of the Sargasso Sea (p. 213), whose common sub-

FIG. 236.—*Ascidia* and two of the animals which it harbours.

A., The whole animal; *B.*, a diagram of a transverse section at the level of the atrial opening; *C.*, a portion of the lattice wall of the pharynx; *D.*, the bivalve mollusc *Modiolaria*, embedded in the tunic; *E.*, the copepod *Doropygus* which inhabits the pharynx.

at., Atrium; *at.o.*, atrial opening; *br.p.*, "brood-pouch" of *Doropygus*, an internal expansion of the oviducts, not a true external brood-pouch; *e.*, endostyle, which secretes the mucus that entangles the food; *g.*, generative organ; *int.*, transverse section of a loop of the intestine; *m.*, mouth; *ph.*, pharynx; *t.*, test or tunic.

The heavy arrows show the direction of the main stream of water through the animal; the light arrows, the course of the food particles to the dorsal side of the pharynx, where they pass downwards to the œsophagus.

stratum is the Weed. The *sublittoral zone* begins with a *coralline belt* of nullipores and ends at the mud belt.

The photic zone is, of all regions of the earth, that which is best fitted to support life and at the same time by diversity of conditions to encourage the evolution of various types of living beings. It is here, probably, that life began and the principal groups of organisms were established.

The *Intermediate Zone* of the bottom is a region of twilight and mud. It is colder and stiller than the photic zone. It extends

for some hundreds of fathoms down the continental slope, merging gradually into the abyssal zone, which is reached at a depth that

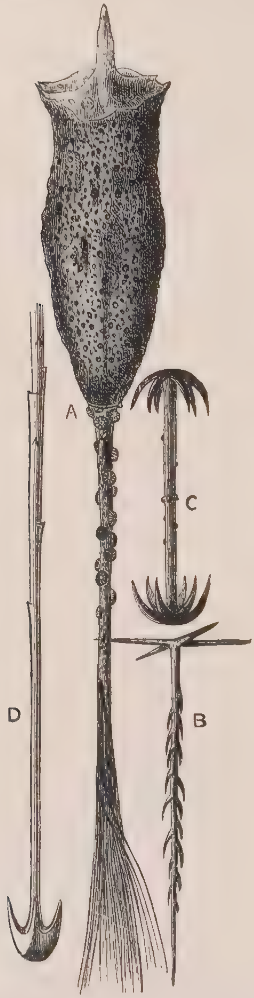

FIG. 237.—*Hyalonema thomsoni*, a glass-rope sponge from 550 fathoms.—From Miss Sollas, after F. E. Schulze.

A., A whole specimen, showing the rooting tuft (glass-rope) coated with a colony of a species of *Epizoanthus* (Zoantharia), which lives in synœcy with the sponge; *B.* and *C.*, spicules from the body of the sponge; *D.*, the free end of one of the long spicules of the rooting tuft, with its grapnel.

varies with the penetration of the sun's rays, but may be said generally to be below 500 fathoms. The muddy bottom of the

intermediate zone is composed largely of the finer particles carried down by rivers or torn from the land by waves, the coarser fragments having been deposited inshore in shallower waters. The mud, of course, varies in composition with the rocks from which it has been derived; round coral reefs and islands it consists mainly of exceedingly fine particles of disintegrated coral: off volcanic islands and coasts composed of volcanic rocks it is volcanic mud. The remains of surface organisms which it contains are masked by these materials. Plant life has practically ceased in this zone. Its fauna, though less numerous and varied than that of the photic zone, is still plentiful, for the mud contains a great quantity of minute organic particles which serve for food. In appearance the animals are unfamiliar, beginning to assume the peculiarities of the deep sea fauna, and in particular often having very large eyes, by which they can make use of the glimmer of light that is granted to them.

The "archibenthic" fauna, as that of the intermediate zone is sometimes called, passes insensibly into the true deep sea fauna of the *Abyssal Zone.* This, in correspondence with its peculiar conditions of life, is the most remarkable assemblage of animals, to human eyes, that exists upon the surface of the globe. It is living in very uniform and constant conditions—in perfect stillness; in cold, often ice-cold, water; in pitch darkness, save where the phosphorescence of some of the animals sheds a pale light; under an enormous pressure, which amounts to about a ton to the square inch for every thousand fathoms; in the absence of plant life, save for some bacteria; and upon wide, gently rolling plains, covered at least to a depth of several feet with an "ooze" composed of the finest particles, mingled with a small but variable proportion of larger objects, chiefly pieces of pumice stone and the indestructible parts of the bodies of animals. The ooze varies with the distance from land, the depth, and the nature of the pelagic fauna above it. Where great rivers bring their suspended materials into the ocean the mud-belt may extend for hundreds of miles into the deep sea, but as a rule it reaches only some 100 to 200 miles from the coast. Beyond that the basis of the ooze is probably volcanic and desert dust, which is borne by the wind for immense distances, as was shown by the way in which the eruption of Krakatoa, charging the air with its dust, affected the colours of sunset all over the globe. With this are mingled in varying proportions the shells and skeletons of pelagic organisms. In depths of less than some 2500 fathoms those which are calcareous preponderate. Usually these are chiefly shells of foraminifera; and such deposits are

called, from the commonest of the genera found in them, *Globigerina* ooze. Some 48 million square miles of the sea bottom are

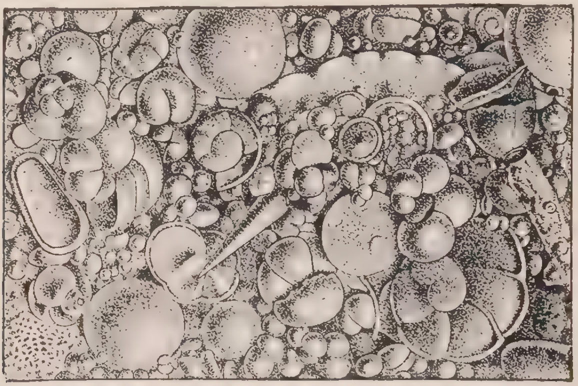

FIG. 238.—Globigerina Ooze.—From Hickson, after Agassiz.

covered with this deposit. Sometimes the shells of pteropod molluscs are so numerous that the calcareous ooze is called after

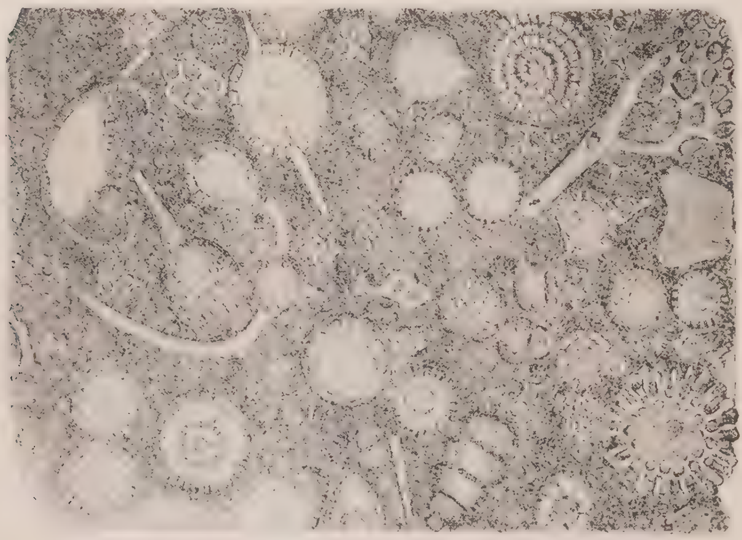

FIG. 239.—Radiolarian Ooze.—From the "Challenger" Report on Deposits.

them. This occurs in a comparatively small area, mostly in relatively shallow waters of the tropics. In deeper waters than

those in which the *Globigerina* oozes lie, the pressure and the high proportion of carbon dioxide in the water bring about the solution of calcareous shells; and then the deposit consists of the volcanic dust with or without a proportion of siliceous skeletons. When these are numerous, they give rise to Diatom Ooze or Radiolarian Ooze, according to the organisms from which they are principally derived. When they are lacking, owing either to the small numbers of their organisms on the surface or to their solution, which takes place in great depths, there results the Red Clay, an

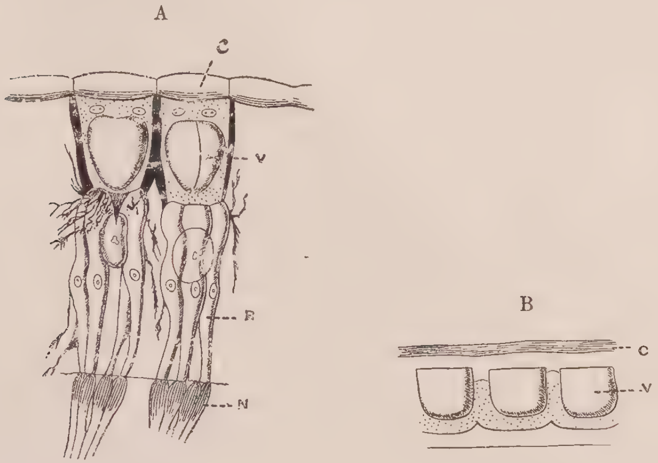

FIG. 240.—Diagrams of sections through the eyes of two species of isopods of the genus *Serolis*.—From Hickson, after Beddard.

A., *S. scythei* (4–70 fms.); *B.*, *S. bromleyana* (400–1975 fms.); *C.*, lens; *N.*, nerve; *R.*, rhabdome; *V.*, crystalline cone.

ooze which is the most widespread of all deep sea deposits, covering an area of about 50 million square miles.

In these peculiar conditions the deep sea fauna is enabled to exist by a number of remarkable adaptations. Some of these affect the *eyes*, which are often greatly enlarged, both in fishes and in crustaceans, and sometimes, in fishes and cuttlefishes, raised as telescope-like cylinders which are adapted to discern moving objects in a dim light. On the other hand, the eyes of many deep sea animals of various classes are so degenerate that their possessors must be blind. Blind and large-eyed animals may be brought up in the same haul of the dredge, which adds to the difficulty of realizing what are the conditions of light in which they are living. Possibly in such places there is a dim light given

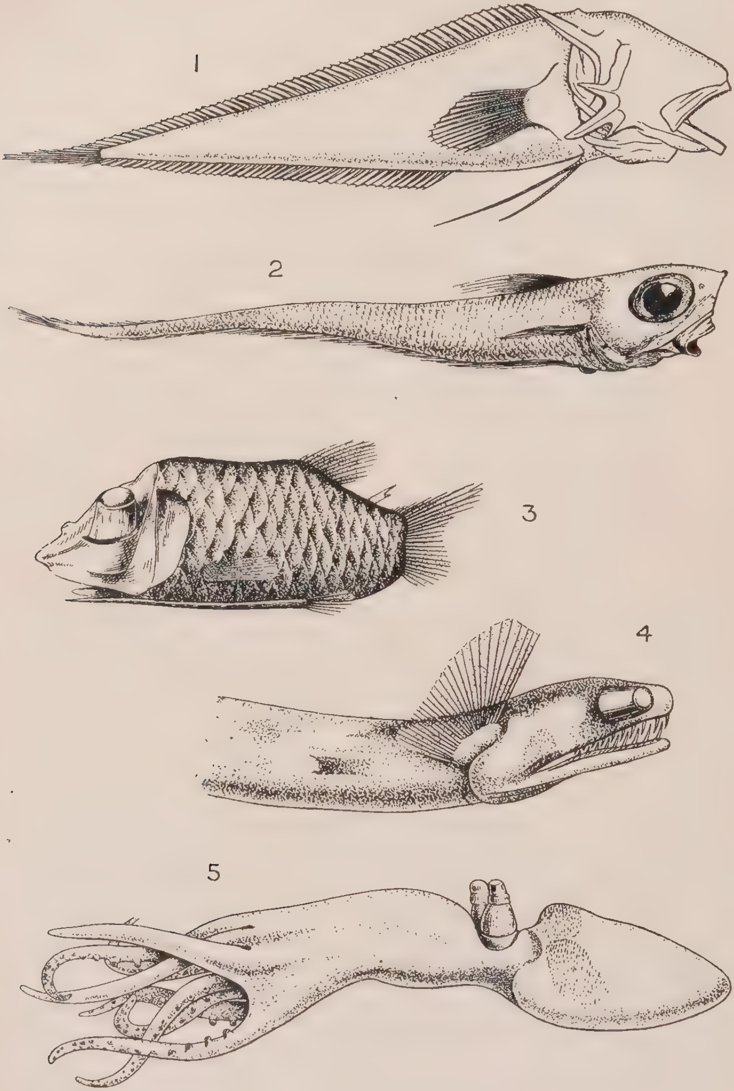

FIG. 241.—Deep sea animals with special features of the eyes.
1 after Alcock ; 2–5 after Chun.

1, A blind fish (*Tauridophidium hexti*), from 1310 fms. in the Bay of Bengal ; 2, a large-eyed fish (*Cœlorhynchus fasciatus*), from 250 fms. on the Agulhas Bank ; 3, a fish with upwardly directed telescope eyes (*Opisthoproctus soleatus*), bathypelagic in the Gulf of Guinea ; 4, a fish with forwardly directed telescope eyes, bathypelagic in the Gulf of Guinea and the Indian Ocean ; 5, a telescope-eyed cuttlefish, bathypelagic in the Agulhas current.

by the phosphorescence of certain members of the fauna. Here again we are met by a problem. *Phosphorescence*, which is due to the oxidation, without the production of heat, of some substance, probably of a fatty nature, manufactured by the protoplasm, is a very widespread phenomenon among the deep sea, as among the pelagic fauna. Often the light is emitted by elaborately constructed organs, as in certain fishes and crustaceans, with a pigment backing, a lens which almost suggests a bull's-eye lantern, and sometimes even a reflector. In other cases the organs are much simpler, and there may be merely a general phosphosescence of the surface of the body, or clouds of a phosphorescent secretion may be poured out, as in the prawn *Heterocarpus alphonsi*. Fre-

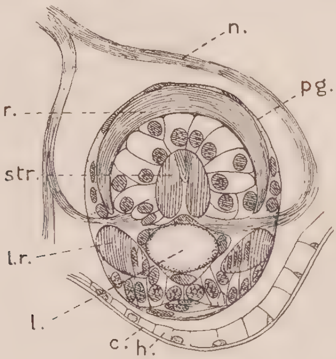

Fig. 242.—A section through one of the thoracic phosphorescent organs of the pelagic crustacean *Nematoscelis* (Euphausiacea).—From Calman, after Chun.

c., Cuticle; *h.*, hypodermis; *l.*, lens; *l.r.*, ring of lamellæ surrounding the lens; *n.*, nerve; *pg.*, pigment; *r.*, reflector; *str.*, striated body.

quently the phosphorescent organs are arranged in rows along the body, as in various fishes and crustaceans, or so placed that they must cast searchlight beams before the animal as it swims. They may give coloured light, red, green, or yellow. If phosphorescence were found only in animals with eyes, it would be easy to imagine its use, but it is found in eyeless zoophytes and starfishes. It has been suggested that in these it serves to attract prey, as it almost certainly must in a fish, related to the "Fishing Frog" (*Lophius*), whose "bait" is phosphorescent; but that can hardly be the case when the animal feeds merely by swallowing the ooze with its organic contents. In any case phosphorescence is so common among deep sea animals that it may be supposed that those of them which have very large eyes are able to see by it, dim though it be. The

blind members of the fauna are those that have given up the attempt, and grope their way, often with the aid of long streamers on their fins, etc. The *colours* of deep sea animals are nearly always uniform, black, grey, white, or red, more rarely blue or purple, but seldom striped or spotted. The red colour, which is a feature that would not be expected, is said to be due to a change in the pigment of the same kind as that which takes place when a lobster is boiled. It is suggested that since such light as there is has probably a greenish tinge, red, the complementary colour, would

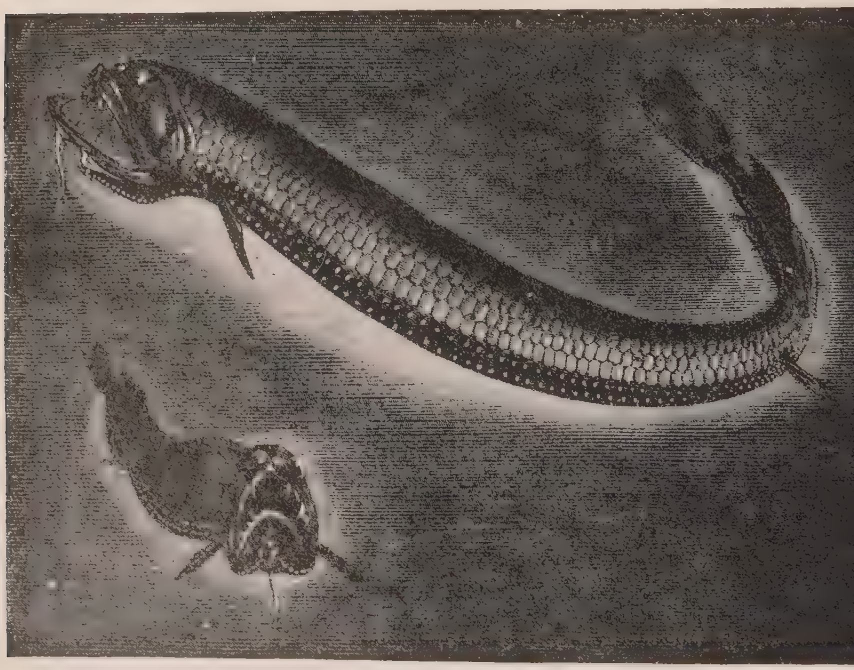

FIG. 243.—*Stomias boa*, a phosphorescent fish taken at a depth of 1900 metres. Less than half natural size.—From Hickson, after Filhol.

by it appear an inconspicuous grey. Another mysterious feature is the *lack of lime* in the shells and skeletons even of animals that lie on calcareous ooze. Possibly it is connected with the absence of violent movement in the water. With the same circumstance we may connect the *slenderness and elegance of build* which is common in the deep sea fauna. The large proportion of species in which a *larval stage is suppressed*, so that development is "direct," is understandable in view of the distance at which the animals live

from the surface waters where such larvæ nominally swim or float. Often, though by no means always, deep sea animals are immensely *larger* than their shallow water relatives. Thus the isopod crustacean *Bathynomus* reaches a length of 9 inches. and the pycnogonid *Colossendeis* a span of 2 feet, while the ostracod *Gigantocypris* is as big as a cherry. This again is at present an unexplained

FIG. 244.—*Bathynomus giganteus*, a giant isopod from deep water. About half size.—From Calman, after Milne-Edwards and Bouvier.

fact. Finally, many of the fixed animals possess *long stalks* by which they are raised above the smothering ooze.

The food of the abyssal fauna reaches it from above in the rain of dead organisms from the teeming multitudes on the surface. Most of these are minute, and their bodies are swallowed in the ooze upon which many deep sea animals feed. The rest of the fauna are carnivorous, devouring the mud-feeders and one another, and many of the fishes are provided with enormous mouths and

a terrific apparatus of teeth for the purpose, while some have the habit of swallowing prey of nearly their own size, which they

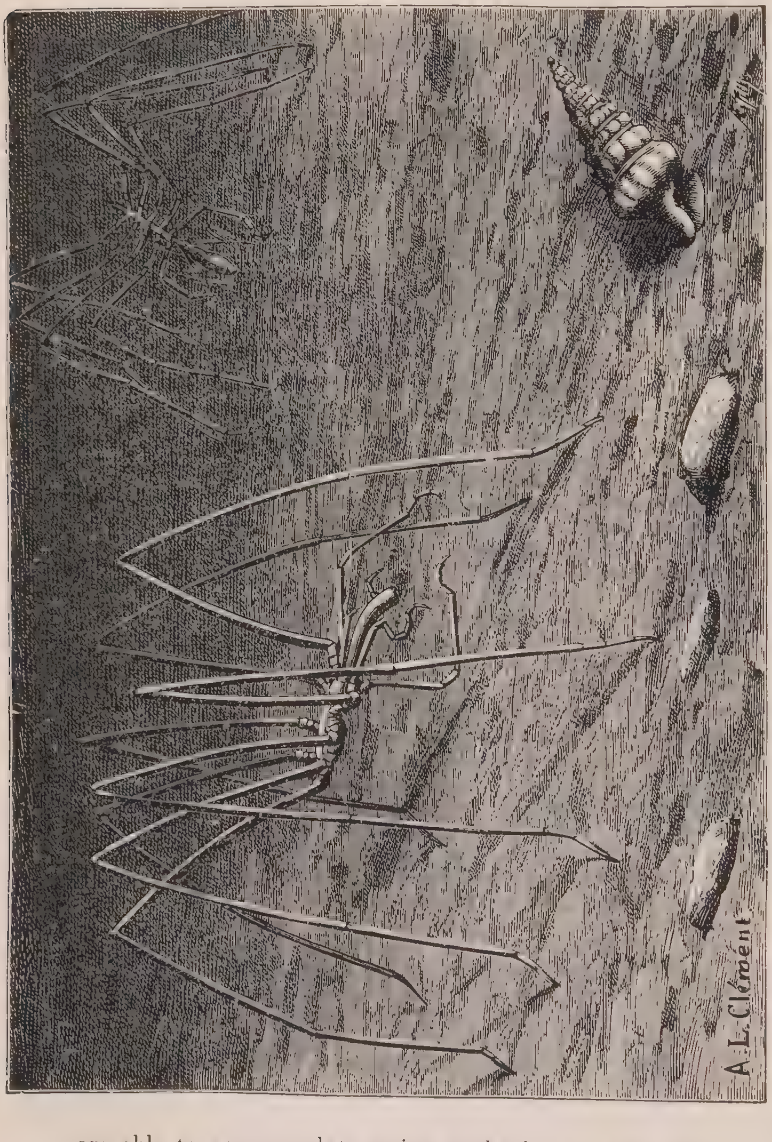

FIG. 245.—*Colossendeis arcuatus*, a giant pycnogonid or "sea-spider" from deep water.—From Hickson, after Filhol.

An example of a widespread Arctic, Antarctic, and deep-sea genus. The largest species (*C. gigas*,

are able to accommodate owing to the fact that their bellies are enormously distensible.

FIG. 246.—*Saccopharynx ampullaceus*, a deep-sea eel, with a large fish which it has swallowed showing through the elastic skin of its belly.—From Hickson, after Gunther.

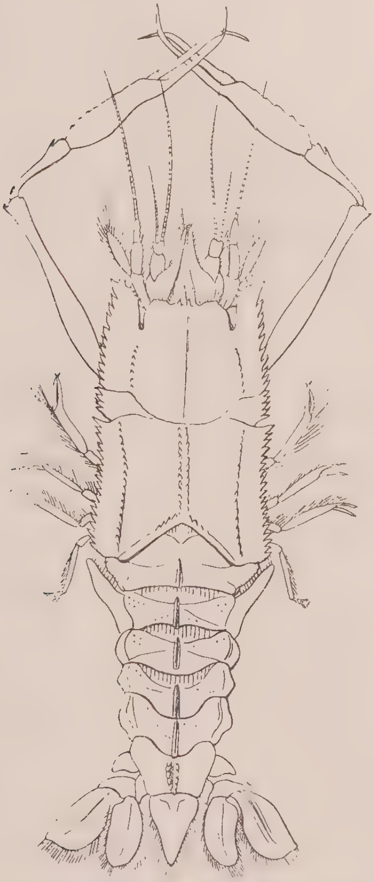

FIG. 247.—The blind deep-sea crustacean *Polycheles baccata* (Eryonidea).—From Hickson, after Spence Bate. Note the absence of eyes and eyestalks.

The deep sea fauna comprises members of most groups of marine animals, but in different proportions from those in which they are present in the shallow water faunas. Corals, annelid worms, crabs, and molluscs are relatively scarce. Echinoderms and siliceous sponges are very numerous. Few of the genera are of ancient types; for the most part they are highly modified representatives of modern shallow water families. Only in a few cases (stalked sea-lilies, hexactinellid sponges, eryonid crustaceans, the irregular sea-urchin *Pygastrides*, etc.) does the deep sea harbour survivors of groups that were more common in earlier ages. Probably, then, it has mainly been populated by immigration from shallow waters in comparatively recent times. In many respects its fauna resembles those of the Arctic and Antarctic Seas, but it is not clear whether this be due to similar species arising in similar conditions, or to a migration of polar forms of life in the direction of the creep of polar waters, or even partly to a contribution by the deep sea to the northern and southern faunas. Very possibly all three factors have been at work.

The distribution of deep sea animals is often very wide. Thus, of molluscs, *Semele profundorum* has been taken near the Canaries and in mid-North Pacific, *Arca pteroessa* in mid-North Pacific, west of the Azores, and off the West Indies; *Lima goliath* off Japan and Patagonia. Of crustaceans, *Gennadas parvus* is distributed over the northern and central Atlantic, North and South Pacific, and Indian Ocean; *Benthesicymus altus* throughout the Pacific and in the South Atlantic; *Pontophilus abyssi* has been taken on the east coast of the United States and in the Gulf of Bengal; and *Munida microphthalma* in the West Indies, South Atlantic, and South Pacific. On the other hand, the range of deep sea organisms appears sometimes to be strangely restricted, considering how uniform are the conditions of life. Possibly this is due to the lack of free larvæ. At present it is not possible to recognize characteristic local faunas. The richness of the fauna varies with depth, and at the same depth with nearness to land. The deepest-living species have the widest distribution.

Though the *Pelagic fauna* contains many well-known animals, as a whole it is hardly less unfamiliar to most of mankind than that of the deep sea. The zoological student, however, will be acquainted with many of its members and their peculiarities. It contains, in some stage of their life-history, representatives of every marine group of the animal kingdom, and of some that are essentially terrestrial, but the adults of certain classes whose common organization is unfitted to swimming or floating are almost or altogether

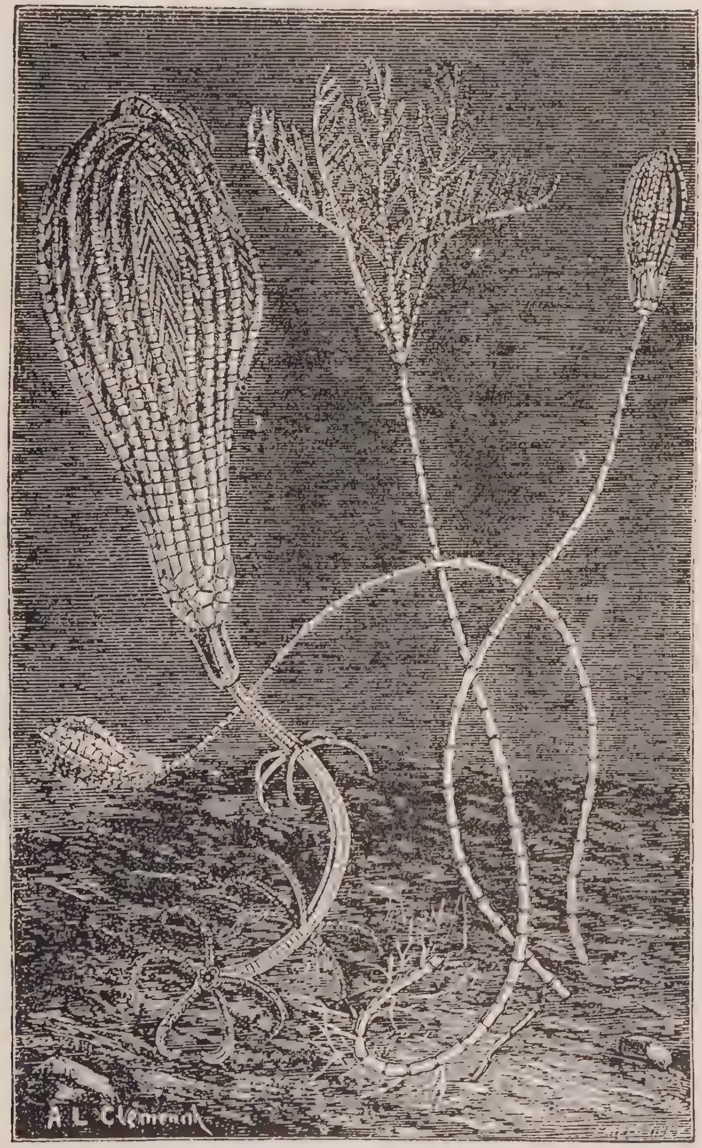

Fig. 248.—Sea lilies from the deep sea.—From Filhol.

1, *Pentacrinus Wyville-thomsoni*; 2, *Rhizocrinus lofotensis*; 3, *Bathycrinus gracilis.*

FIG. 249.—Hexactinellid sponges from the deep sea.—From Filhol.

1, *Alcyoncellum speciosum* ; 2, *Euplectella aspergillum*.

lacking in it. Thus it has no adult sponges, anthozoa (except Minyadidæ), echinoderms (except the remarkable holothurian

Fig. 250.—The Pelagic holothurian *Pelagothuria*.

The short processes are the tentacles which surround the mouth. The long, webbed processes are formed by the ampullæ of the tentacles pushing out the body wall.

Pelagothuria), lamellibranch or ordinary gastropod molluscs (except *Ianthina*), air-breathing arthropods (except the bug

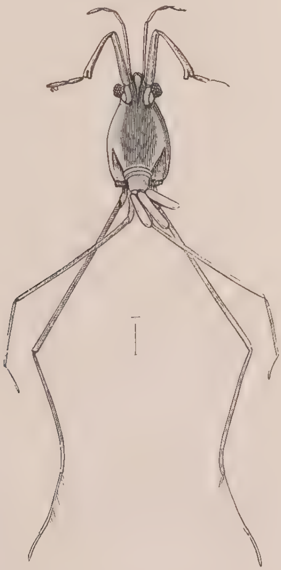

Fig. 251.—*Halobates sobrinus*, a Pacific species of a genus of marine pelagic bugs. The figure represents the under side of a female, carrying eggs. —From Sharp.

Halobates), or birds. Radiolaria, *Noctiluca*, jelly-fishes, siphonophores, ctenophores (Fig. 354), copepods, and various other crustaceans, pteropod and heteropod molluscs, many cephalopods, *Salpa*,

Doliolum, *Pyrosoma*, and the Appendicularians among tunicates, and many fishes and whales, are characteristic of it. The principal respect in which the conditions of life for pelagic animals differ from

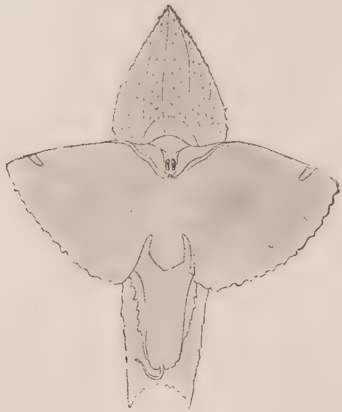

FIG. 252.—A pteropod mollusc (*Cymbulia peroni*), showing the wing-like expansions of the foot.—From Thomson.

those of the bottom fauna is the absence of a substratum, and consequently of the support and opportunities of concealment which it affords. The pelagic region is self-supplying in the matter

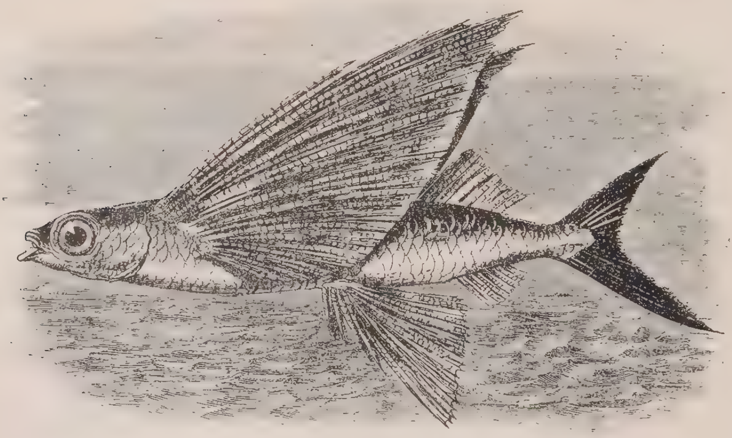

FIG. 253.—A flying fish (*Exocœtus volitans*).

of food, raising and consuming its own crops of floating algæ, and indeed providing a great part of the nutriment of the animals on the bottom. Its peculiarities are more marked in the plankton

than in the nekton. The latter are animals of strong swimming powers, usually darkly-coloured and bluish or slaty above, lighter, often silvery white, below, so that when seen from either direction they are inconspicuous. Whales, sharks, flying fishes, and the Sun fish are well-known members of the high-seas nekton. Mackerel, and the herrings, sprats, and pilchards, are found in the neighbourhood of the coasts. Many cuttlefishes (*Cephalopoda*) belong to the pelagic nekton. Of the peculiarites of planktonic animals, something has already been said. Their commonest feature is an extraordinary *transparency*. This has been supposed to be of service

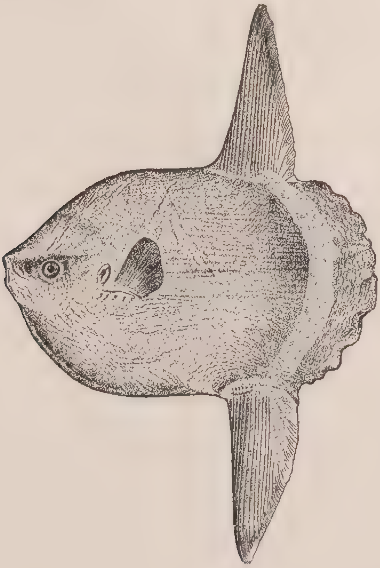

Fig. 254.—The Sunfish (*Orthagoriscus mola*).—From Boulenger.

to them in rendering them invisible, but as many of them are swallowed in masses by animals, such as whalebone whales, which do not search for them by sight, it is probable that the delicacy of their tissues has as its really important result not invisibility, but a very low specific gravity, so that floating is easy. Sometimes, as in salps and heteropod molluscs, the organs of digestion and some other essential functions are concentrated as a small opaque nucleus in the transparent body. *Buoyancy* is attained by various other expedients. Gas floats are found in many of the colonial jelly-fishes known as Siphonophora, in some of which (*Velella* and *Physalia*, the Portuguese Man-o'-war) they stand up above the

FIG. 255.—*Physophora hydrostatica*, one of the Siphonophora.

At the top of the colony is a small float (pneumatophore), containing gas; below is a column of swimming bells (nectocalyces), by whose contractions the whole body is moved; below these a circle of processes, some of which end in mouths, through which the colony feeds. Below these again the very long, branched tentacles spread through the water.

water and, catching the wind, serve as sails ; in the floating anemones of the Minyadidæ, and in the winkle-like *Ianthina*, which

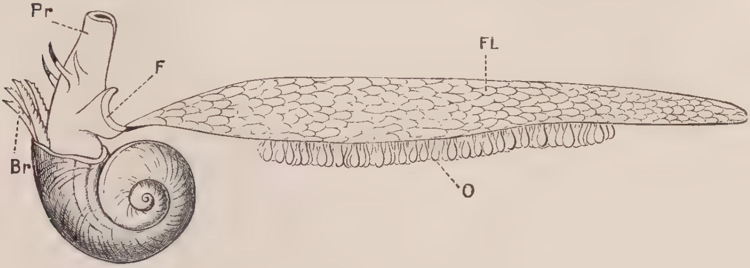

FIG. 256.—*Ianthina fragilis*, a pelagic winkle.—From Cooke, after Quoy and Gaimard.

Br., Gills ; *F.*, foot ; *FL.*, float ; *O.*, eggs ; *Pr.*, proboscis.

forms a float of hardened slime with enclosed air-bubbles. Oil droplets make buoyant the bodies of copepods and fish eggs. The

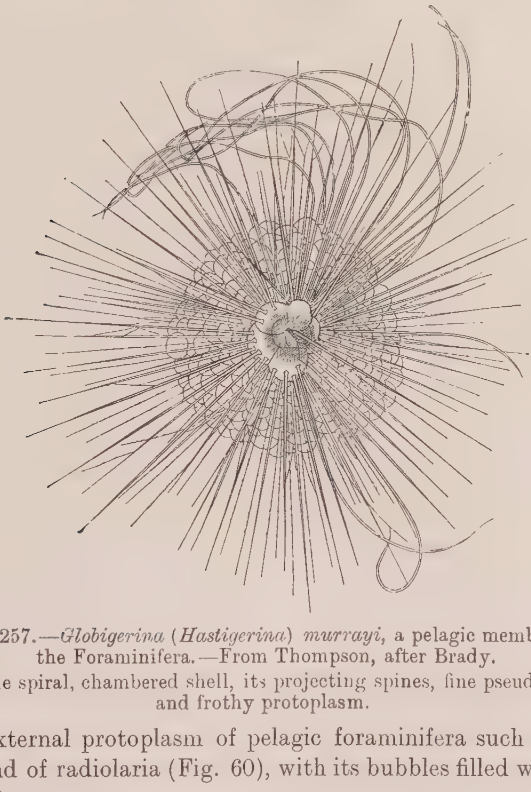

FIG. 257.—*Globigerina* (*Hastigerina*) *murrayi*, a pelagic member of the Foraminifera.—From Thompson, after Brady.

Note the spiral, chambered shell, its projecting spines, fine pseudopodia, and frothy protoplasm.

frothy external protoplasm of pelagic foraminifera such as *Globigerina*, and of radiolaria (Fig. 60), with its bubbles filled with water

of low specific gravity from the absence of salts, fulfil the same function. Sinking is retarded also by a great development of spines such as those which give their remarkable appearance to the larvæ of various crustaceans and worms, or form the beautiful skeletons of radiolarians, or adorn the shell of *Globigerina*. *Phosphorescence* is common, and as difficult to explain here as in the deep sea. Its effect in lighting up the sea surface at night is well known.

The *vertical movements* of the plankton are not completely understood. On the whole there is an upward movement at night and a downward movement in the day and in bad weather, but the species do not all move at the same time, or to the same depth. The movements are often surprisingly sudden, clearing the surface in a few minutes. They must be carried out in different ways. An animal, such as a copepod, which supports itself mainly by its exertions in swimming, has only to cease these in order to sink. Frothy protozoa are said to burst some of their bubbles to the same end. In other cases the mechanism is not clear. The plankton differs with the locality. Its *distribution*, and that of the nekton, which feeds upon it, is influenced by various factors, partly by salinity, to which the fauna is sensitive, as may be seen by the sinking of the surface fauna during rain, and the progressive falling-off of the plankton from west to east in the Baltic. Temperature, however, is probably the principal determining factor. Not only do the species vary with it, but the population is denser in cold water and more diverse where it is warmer. Possibly this is due to a lessened activity of the denitrifying bacteria at low temperatures, so that there is more food for the plants on which the animals are nourished ; and to some depressing effect of cold upon variation, which seems to show itself in other faunas also. Besides the geographical differences in the plankton, there are in many localities seasonal changes in its composition.

As subfaunas of the pelagic region, we may first distinguish that of the *Neritic zone* from that of the *Oceanic area*. The *Neritic zone* lies around the coasts, corresponding roughly in extent with the photic zone of the bottom, and is distinguished by the presence of numerous larvæ of bottom forms and the absence of characteristic members of the oceanic plankton. Its conditions and consequently its fauna are much more variable than those of the open sea. The *Oceanic area* may be divided into zones according to depth. Its *Photic zone* extends downwards to a level which near land is that at which the neritic zone and the photic zone of the bottom also end, but as it is followed outward, lies deeper as the waters become clearer, till in the tropics at a distance from land

it may be as low as 500 fathoms. The fauna of this zone varies much with locality. Thus, for instance, there are special types of it in the Arctic, northern, western, south-eastern, and south-

FIG. 258.—Members of the neritic marine plankton.

1, *Noctiluca*, a large, phosphorescent flagellate; 2, medusa of a hydroid; 5, a worm related to *Nereis*; 6, a crustacean related to *Cyclops*; 8, the Arrow worm (*Sagitta*); 3, 4, 7, larvæ of a sea-urchin, a worm related to *Nereis*, and a crustacean related to the lobsters. Many other bottom-living forms are distributed in larval phases such as these.

western parts of the North Atlantic. Below it there take place the series of changes which also mark the lower limit of the photic zone of the bottom (p. 220). Notably the altered viscosity of the water delays sinking of the bodies of the surface fauna, and produces

what has been called an "artificial bottom," corresponding to the mud-line, upon which a special twilight fauna equivalent to that of the intermediate zone of the bottom appears to feed. Many of the animals of this pelagic *Intermediate zone* have the colours, eyes, phosphorescent organs, etc., of the deep sea. Deeper still is a vast *Abyssal zone*, extending to the bottom, and possessing probably a very scanty fauna. Among the animals that are characteristic of this zone are the deep-sea radiolaria of the Challengeridæ.

FIG. 259.—*Tuscarora*, a radiolarian of the Family Challengeridæ, taken at depths of 500 fathoms and over.—After Chun.

Only one ray of the shell is shown in its full length.

Certain terms that are often applied to parts of the sea may here be explained. The *Neritic area* surrounds all land, within the limits of the 100 fathom line. Its fauna includes that of the photic zone of the bottom and the neritic pelagic fauna. The *Oceanic area* includes the whole of the rest of the ocean. The *Photic zone* in the wide sense of the term comprises all waters down to the level at which sunlight ceases to affect organisms other than those provided with specially developed eyes, that is, those of the neritic area and of a somewhat deeper layer of the oceanic area. The *Aphotic or Deep Sea zone* comprises all waters below this. The *Twilight or Intermediate zone* is that immediately below the photic zone, where the light is dying out. It has a bottom only near land, where it overlies the upper part of the continental slope. This bottom comprises much of the *mud belt*, but that, as we have seen, varies in extent. To seaward, the twilight zone includes the "artificial bottom" already described. The *Abyssal zone or area* comprises all waters below the twilight zone, which passes insensibly into it and cannot be

sharply defined from it. To these names of areas roughly correspond certain terms that are applied to the fauna. The *epibenthos* is the benthos of the neritic area. The *mesobenthos* is that of the twilight

FIG. 260.—*Umbellula güntheri*, a deep-sea alcyonarian zoophyte with a long stalk.—From Hickson, after Agassiz.

area. The term *archibenthos* is sometimes applied to it. The *hypobenthos* is the benthos of the abyssal area. The *epiplankton* is the pelagic fauna [1] of the photic zone. It includes that of the neritic area and that of the photic zone in the oceanic area. The *mesoplankton* should be the corresponding fauna of the twilight zone. Actually, however, it is usually applied to the whole pelagic fauna below that of the photic zone. Similarly the *hypoplankton* should be that of the whole water of the abyssal zone, but the term is usually applied to the plankton of the water immediately over the bottom.

[1] The term "plankton" is often used as synonymous with the "pelagic fauna," including both plankton proper and nekton.

CHAPTER X

THE FRESHWATER FAUNA

In comparing the sea with fresh waters as a habitat for animals, we have already seen what are the general conditions under which freshwater life is carried on. Briefly to resume them, it may be said that not only are fresh waters less salt, and therefore less dense and less viscous than the sea, but in them sundry conditions—salinity, reaction, temperature, and movement—vary more often and within wider limits than in the ocean; that they are liable often to dry up and sometimes to freeze through; but that they are not subject to tides; that they are on the whole more turbid than marine waters; that in them the current flows in one direction, tending always to remove their fauna to the sea; and, lastly, that, whereas the sea is continuous and its faunas are separated only by impalpable barriers, such as differences of temperature and salinity, fresh waters are discontinuous, and migrants from one of them to another must pass through the air or the salt water of the ocean.

To these conditions there correspond certain characters of the freshwater fauna. It contains a larger proportion of eurythermal animals than the marine fauna, and the remainder of its members are probably less stenothermal than the bulk of sea animals. Often there are special arrangements for enduring seasons when either the temperature is unfavourable or the water is removed by drought or frost. This is seen in the winter sleep of some fishes (carp, etc.) and the summer sleep of others, such as the Lung Fishes (*Dipnoi*). At such times the animals often retire to the mud, which may become dried around them. Other members of the fauna pass such periods either as adults (protozoa, as *Amœba*; some copepods, as *Canthocamptus*, rotifers, nemertine worms, etc.), or as eggs (*Hydra*, cladocera, rotifers, flatworms, etc.), or as buds (gemmules of *Spongilla*, statoblasts of Polyzoa), enclosed in horny or slimy cysts, which may be secreted as in *Hydra*, etc., by an egg or, as in cladocera, provided by the parent. It has been proved experimentally that these structures can resist both frost and drought: indeed their germination is often improved by temporary exposure to those conditions.

In *Spongilla* and polyzoa the case contains air spaces, which both render it non-conducting, and enable the gemmule to float and thus more readily to be distributed. A remarkable feature of the freshwater fauna, due, perhaps, to its seasonal life, is the frequent occurrence of parthenogenesis in the life-history of its members, as, for instance, in cladocera and rotifers. In these cases it is only from fertilized ova that the encysted "winter eggs" are produced. The males, whose presence makes their production possible, are usually not born in every generation, but appear after several of the quickly-succeeding parthenogenetic broods. This happens at different seasons in different cases, sometimes more than once in the

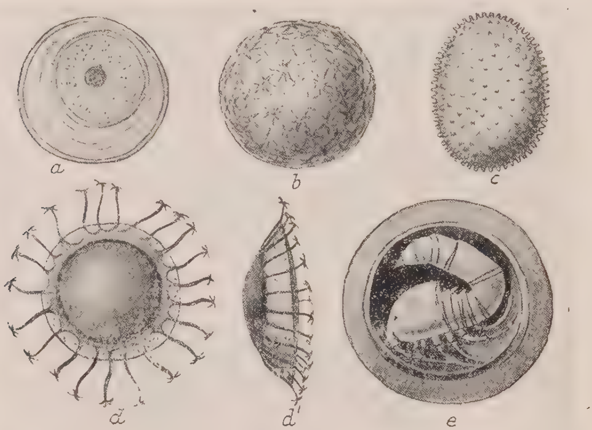

FIG. 261.—Animals in the encysted condition.—After various authors.

a., The ciliate *Colpoda*; *b.*, the gemmule of a freshwater sponge (*Ephydatia fluviatilis*); *c.*, the resting egg of a rotifer (*Polyarthra platyptera*); *d.*, *d'.*, the statoblast of a polyzoon (*Cristatella mucedo*, Fig. 212); *e.*, the copepod *Canthocamptus*.

year, and by no means always just before the onset of winter. The circumstances which bring it about are not understood, but temperature, if it have any influence, is not the most important of them. We have already commented upon the frequent suppression of a free larval stage in freshwater animals, upon the remarkable absence among them of sessile forms with calcareous skeletons, and upon their susceptibility to strongly saline water.

Paradoxically enough, we must count among the characteristic peculiarities of this aquatic fauna the custom of breathing air. Not only do the members of its large contingent of immigrants from the land always, as we shall see, retain this habit, but many that are indisputably of water ancestry have acquired it. Not merely

the ganoid and dipnoan fishes, but also many of the Teleostei, including a number of the "coarse" fishes of our own waters, breathe air regularly, absorbing the oxygen by the lining of parts of the alimentary canal. Some, such as the Bleak and Roach, are so dependent upon the habit that they may be drowned by preventing them from coming to the surface to take gulps of air. The Apple Snails (*Ampullaria*) of Africa and South America have their mantle-chamber divided by an incomplete partition into a lung and a gill chamber. In the true Water Snails (*Limnæa*, etc.) the gills are lost and there is only a lung. It is interesting to note that in deep

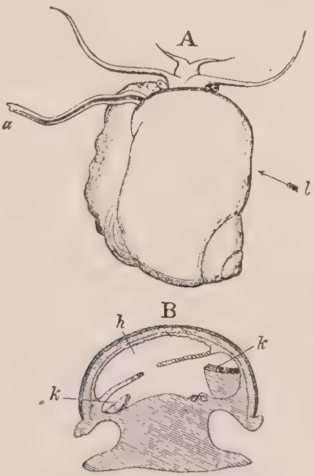

FIG. 262.—*Ampullaria insularum*, one of the Apple Snails.—From Semper.

A., The whole animal ; *B.*, a section (in the direction of the arrow in *A.*).
a., Siphon ; *h.*, upper lung cavity ; *k.*, gills in gill cavity.

lakes this is filled with water. These creatures are by no means all inhabitants of foul or turbid waters, and it seems probable that the great advantages which air possesses as a respiratory medium have been seized upon by many members of the aquatic fauna which were not compelled to do so by any particular unsuitableness of the water in which their lives are passed. Those advantages we have already mentioned severally in the discussion of various topics. Briefly enumerated, they are as follows. Air contains more oxygen than is dissolved in water ; its composition is more uniform than that of the liquid medium ; it is more easily renewed in the cavities of the body, because it is more mobile ; it is more readily kept pure by diffusion while it lies in the interstices of the organs ;

and it is less liable to contain poisonous substances. We have seen that the various forms of apparatus for making use of it in respiration draw it in and out of cavities, instead of passing it in a continuous current over the respiratory surface

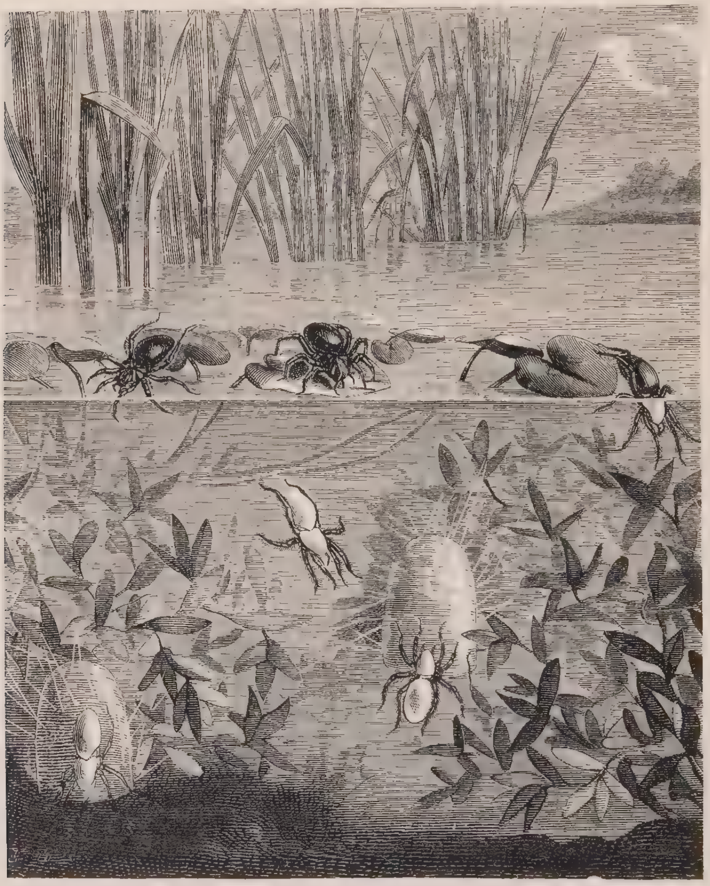

FIG. 263.—The Water Spider (*Argyroneta*).—From Duncan.

or moving the latter in it, as do organs for water-breathing. It may be added that they are usually more intricate. That the breathing of air has not been taken up by marine animals is perhaps due mainly to the depth of their habitat and to its troubled surface, though the more frequent foulness, or turbidity, or both, of fresh waters cause air breathing there to have further

advantages. Even between tide marks, marine animals, though with their water-breathing organs they may be well able also to breath air, as are, for instance, the Shore Crab (*Carcinus*) and Periwinkles, do not adopt the habit when they are submerged.

Special peculiarities of the freshwater fauna accompany variations in the composition of the medium. The most important of the salts in this respect are those of calcium. A whole series of

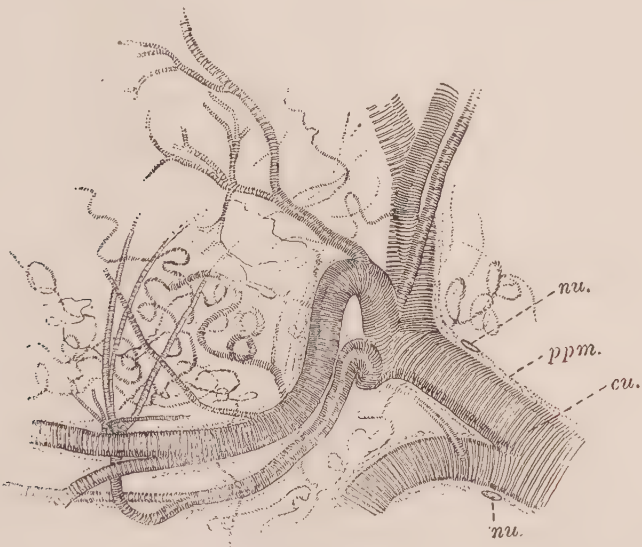

FIG. 264.—Tracheæ of a cockroach, highly magnified, to show the small size and great complexity of the spaces into which the air is drawn or diffuses.

cu., Cuticular lining with spiral thickening; *nu.*, nuclei of the protoplasmic layer; *ppm.*, protoplasmic layer continuous with the epidermis ("hypodermis") of the surface of the body.

animals—sundry rhizopod and flagellate protozoa, rotifera, cladocera, etc.—live only in soft waters; on the other hand, animals with calcareous shells usually, though not always, have these less strongly calcified in such waters. The reaction of the water is also of importance: fishes, for instance, are said to thrive best when it is slightly acid. The majority of the fauna seek well-oxygenated water. Some, however, live only, or by preference, where decaying matter is present, and consequently where free oxygen is scanty. We have seen how certain of these contrive to do without it by becoming anaerobic. Among the members of this fauna of impure water (not all equally able to dispense with

oxygen) are many ciliate protozoa, such as *Paramecium*, *Tubifex*, and other oligochæte worms, nematodes, larvæ of *Eristalis* and other flies, etc.

We have also already noted and endeavoured to account for

FIG. 265.—*Plumatella*, a polyzoon of fresh water.

the fact that the freshwater fauna is less rich and varied than that of the sea. Of the larger groups of animals, it lacks altogether representatives of the Radiolaria, calcareous Foraminifera (*Polythalamia*), calcareous and horny Sponges, Anthozoa, Siphonophora, Ctenophora, Mesozoa, Gephyrea, Chætognatha, Cirripedia, Pycno-

gonida, Amphineura, Heteropoda, Pteropoda, Cephalopoda, Echinodermata, Brachiopoda, Pterobranchia, Tunicata, and Cephalochordata. Of some others, as the Siliceous Sponges, Polyzoa, Hydrozoa, and Scyphozoa, it has but few representatives. Only the Dipnoi and Amphibia are found in it and not in the sea; though it has the majority of species of the Heliozoa, Rotifera, Oligochæta, Branchiopoda, water insects and mites, and ganoid fishes. The majority of its fauna must be descended from ancestors which reached it from salt water, but it has a much larger number of immigrants from land than the sea possesses. Spiders, mites, insects, snakes, and possibly dolphins[1] entered it in this way.

It is interesting to note that, while many of these animals of land descent[2] have special adaptations to swimming, such as broadenings of limbs or of tail, they all retain the habit of breathing

FIG. 266.—The Water Scorpion *Nepa cinerea.*—From Furneaux.

air, and thus continue to avail themselves of the chief advantage which that medium possesses over water, namely, its greater suitability for respiration. Most aquatic air-breathing animals come to the surface to take the air into their respiratory passages, but some insects must renew the gases in their respiratory system by interchange with those dissolved in the water. Aquatic insects present an extremely remarkable series of arrangements by which it is possible for them to continue the breathing of air. Many of them, both adults and larvæ, have at the hinder end of the body openings, often placed at the end of tubes, which they raise to the surface of the water, there to take in the air. Such are the water Scorpions (*Ranatra* and *Nepa*), and the larvæ of the fly *Eristalis* and of gnats

[1] The earliest undoubted Cetacea were related to the Dolphins of fresh water.

[2] Some of the animals referred to in the following paragraph should perhaps be referred to the amphibious fauna, since they pass much of their time on land and hunt there for food.

and mosquitoes. In the pupæ of mosquitoes and gnats there are similar tubes upon the back. Other insects, as the Whirigig and Great Water Beetles (*Gyrinus* and *Dytiscus*), carry down with them a supply of air held as a bubble between the wing-covers and the back. Others, as the Black Water Beetle (*Hydrophilus*) and the Water Boatman (*Notonecta*), and also the Water Spider (*Argyroneta*, Fig. 263), are coated with a shiny layer of air entangled in a coat of down which covers

FIG. 267.—*Ranatra linearis.*—From Furneaux.

their bodies. *Hydrophilus* renews this air by ladling down a further supply with its hairy antennæ. *Argyroneta* spins a silken house, like an inverted thimble, which it fills with air. In this it rests and lays its eggs. More truly aquatic modes of respiration, however, are found in the larvæ of various insects. In these the gases in the tracheæ are renewed through interchange by diffusion with those in solution in the water. In a few cases (for instance, in certain stone-flies, lepidoptera, and diptera, as *Chironomus*) the

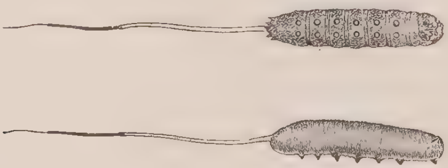

FIG. 268.—The larva of the Drone Fly (*Eristalis tenax*).—From Furneaux.

exchange takes place on the general surface of the body, which is here often supplied with a special set of tracheæ; but in most there are special outgrowths, known as "tracheal gills," situated either in the rectum, as in the larvæ of dragon flies and the nymphs of certain mayflies (*Ephemeridæ*), or more usually on the head or at the sides of the trunk. These are either thread-like, as those of the caddis-fly larvæ (*Trichoptera*), some of those of the Stone Flies (*Perlidæ*), and the tufts on the head of the larvæ and pupæ

of the Sand Midges (*Simuliadæ*); or leaf-like, as in nymphs of the Mayflies. In the latter group they are often protected in various ways, either by being placed on the under side of stout plates, as

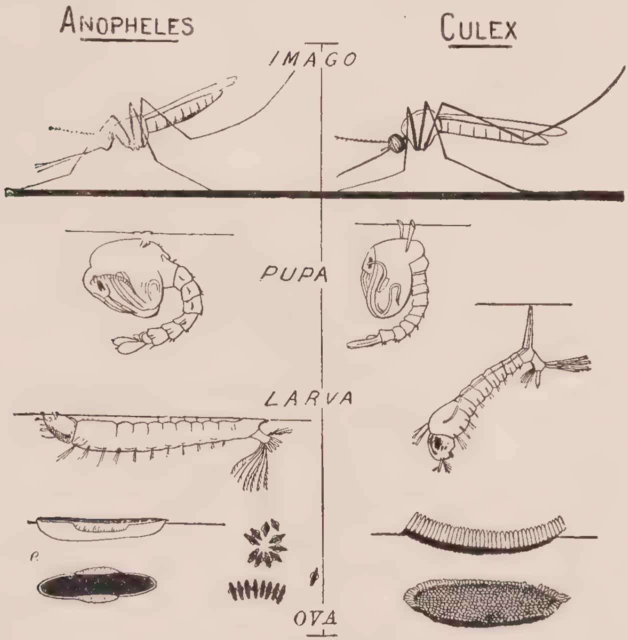

FIG. 269.—A comparison of the various stages in the life-history of a mosquito (left) with those of a gnat (right).—From Shipley.
Note how the larvæ and pupæ hang from the surface film of the water (represented by a thin line). The organs by which they are suspended contain air tubes, and if these be prevented by a film of paraffin from reaching the air the insect is drowned.
e., Two views of an egg, magnified.

in *Oligoneuria*, or by the foremost of them forming a plate that overlaps the rest, as in *Tricorythus*, or by being placed in a special

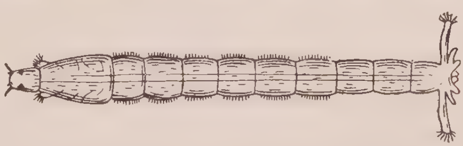

FIG. 270.—A "bloodworm" (the larva of the fly *Chironomus*).—From Furneaux.

gill chamber enclosed by a carapace, formed from the first pair of wings, through which the water flows, entering by two openings behind and leaving by a dorsal one in front. This arrangement is

found in the remarkable, copepod-like nymph of *Prosopistoma*. We have here a series that recalls the respiratory apparatus of various crustacea.

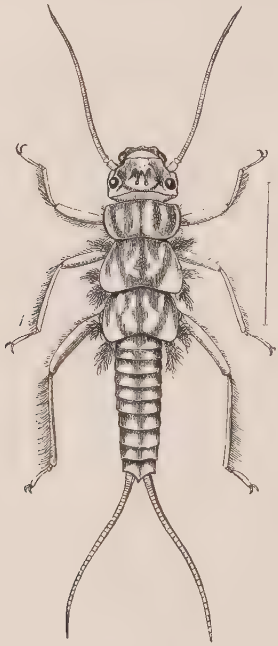

Fig. 271.—The nymph of a species of Stone-fly (*Perla*), showing tufted tracheal gills.—From Sharp.

Fig. 272.—The nymph of a May-fly with leaf-like tracheal gills.—From Thomson, after Eaton.

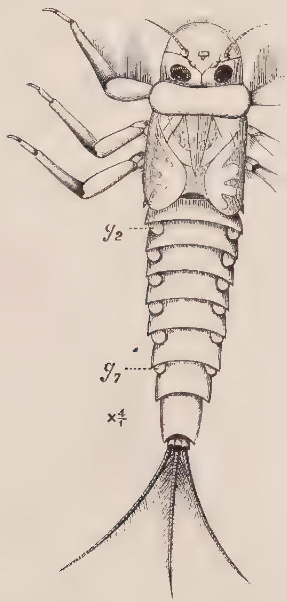

FIG. 273.—The nymph of *Oligoneuria garumnica*, a may-fly, showing plate-like gills (*g.*) on whose under side the tracheæ are placed.—From Sharp, after Vayssière.

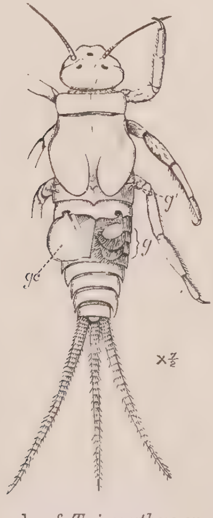

FIG. 274.—The nymph of *Tricorythus sp.*, a may-fly, showing gill cover (*g.c.*) and gills (*g.*).—From Sharp, after Vayssière.

Dolphins and whales, which, as we have seen, perhaps took origin in fresh waters, present a set of adaptations to aquatic life

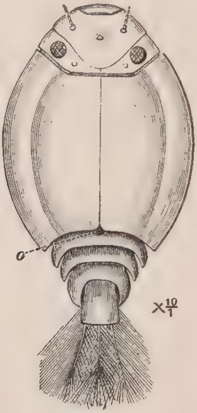

Fig. 275.—The nymph of *Prosopistoma punctifrons*, a may-fly.—From Sharp, after Vayssière.
o., Outlet of gill-chamber.

which are quite as remarkable as the respiratory apparatus of water insects. (i) Their body is shaped like that of a fish, and has no

Fig. 276.—The Ganges Dolphin (*Platanista gangetica*).

projecting ears, hind limbs, or fur, but is covered with smooth skin; thus it is adapted to travelling swiftly through the water. (ii) The forelimbs are turned into paddles, which have the function

of the pectoral fins of fishes. (iii) Often there is also a back fin. (iv) The tail has a pair of broad flukes which increase its efficiency as a swimming organ; but these are horizontal, not vertical like those of a fish, and thus serve better the frequent upward and downward movement which is made necessary by the habit of breathing air. (v) The nostrils are on the top of the head, so that only that part of the body need be raised above the water; and they can be closed. (vi) The larynx is elongated and meets the posterior nares, forming thereby a continuous passage through which air is drawn into the lungs, so that the mouth can be opened under water during breathing. (vii) The vascular system has numerous plexuses or *retia mirabilia*, perhaps to the end of storing more blood and thus more oxygen. (viii) A thick layer of fat, or

FIG. 277.—The Killer Whale (*Orca gladiator*).—From Beddard, after True.

"blubber," beneath the skin retains the heat of the body and thus compensates for the absence of hair, and also makes the body buoyant. (ix) The bones are light. (x) The eyes are small. (xi) Sweat, tear, and salivary glands, all of which would be useless to an animal that lives and feeds in water, are lacking.

As might be expected from their discontinuity and the variation in the conditions of life which they present, the faunas of the fresh waters of different countries differ considerably. What is more remarkable is the cosmopolitan distribution of some fresh-water animals. This, however, is found only in the lower forms of life—protozoa, rotifera, and some cladocera and copepoda. It results, probably, from their possession of the encysted phases to which we have already alluded, and in which they are passively distributed as dust by the wind or in dried mud upon the feet of

water birds. The local races of such species are often merely composed of individuals altered by the direct action of the local salinity, temperature, or food supply upon them during their development, much as these may cause seasonal changes in a species in one locality. Thus it has been shown that *Artemia salina* may be caused by increasing the salinity of the water to pass into the form known as *A. milhauseni*, and by decreasing the salinity to

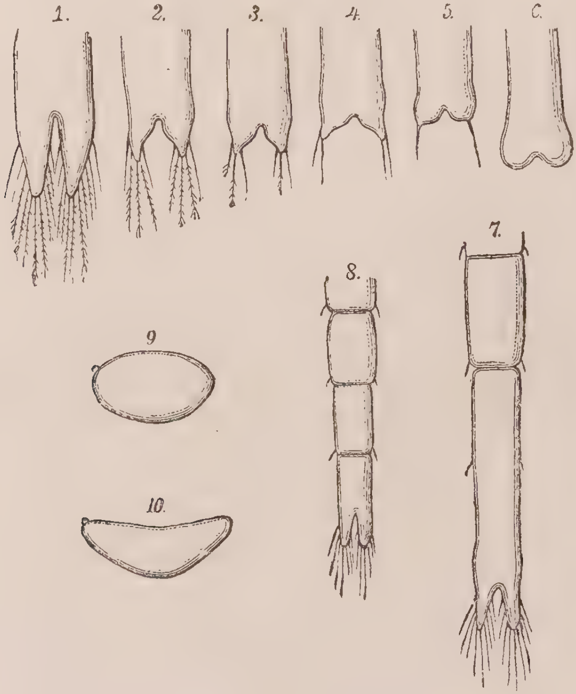

FIG. 278.—Transformations of *Artemia* brought about by alterations in the salinity of its habitat.—From Semper, after Schimkewitsch.

1, The tail-lobe of *A. salina*; 2–5, intermediate stages to 6, the tail-lobe of *A. milhauseni*; 7, end of the abdomen of *A. salina*; 8, the same region of a specimen bred in slightly salt water, resembling *Branchipus*; 9, gill of *A. milhauseni*; 10, gill of *A. salina*.

assume some of the characters of the allied genus *Branchipus*; and again the water flea *Daphnia hyalina* loses in winter the peak on its helmet-shaped head, but can be caused to retain the summer shape in cold water by suitable feeding. It is no doubt largely to this power of distribution that the comparative uniformity of freshwater faunas is due; but, as has already been said, it is also due to their habitats being, geologically speaking, shortlived and

changing, so that time is rarely given for the evolution of peculiar forms.

The fauna of fresh waters falls into two very unequal divisions —those of surface waters and of subterranean waters. (1) It is estimated that of the water which falls upon the land as rain and snow roughly one-third is evaporated, one-third runs off immediately into rivers and lakes, and one-third sinks into the earth, there to join *subterranean watercourses.* Here it is inhabited by a fauna,

FIG. 279.—*Cambarus pellucidus*, the Blind Crayfish of the Mammoth Cave of Kentucky.—From Calman.

only occasionally, in caves and wells, accessible to Man, which lives under quite special conditions. Such waters are of uniform and usually low temperature, quite dark, and without plant life, so that they contain only such food as may be washed down into them. Their fauna is scanty and peculiar. It is stenothermal and psychrophile, scavenging and carnivorous in diet, pallid in colour or transparent, and blind, the eyes being lost or greatly reduced. As examples of its members we may cite the blind white cave newt of S.E. Europe, known as the Olm (*Proteus*), which has already

been mentioned (p. 34); the blind crayfish of the Mammoth Cave of Kentucky (*Cambarus pellucidus*); the British Well Shrimp (*Niphargus aquilex*); the remarkable archaic crustacean *Bathynella*; the blind fish *Amblyopsis spelœa*, found in the river Styx of the Mammoth Cave and in other North American caves; and the flatworm appropriately named *Dendroceclum infernale*. A re-

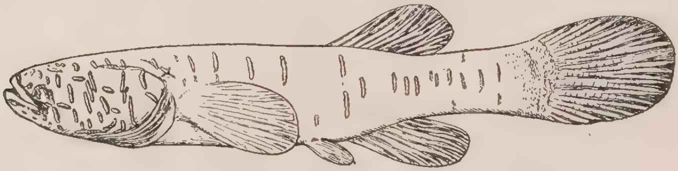

FIG. 280.—*Amblyopsis spelœus*, a blind fish from the Mammoth Cave.

markable feature of this fauna is that many of its members, such as the isopod *Typhlocirolana* and the Cuban cave fish *Stygicola*, are more nearly allied to marine species than to any that are known from fresh waters above ground. It has been suggested that these have been derived from species that have entered the underground waters directly from the sea through submarine fissures in the

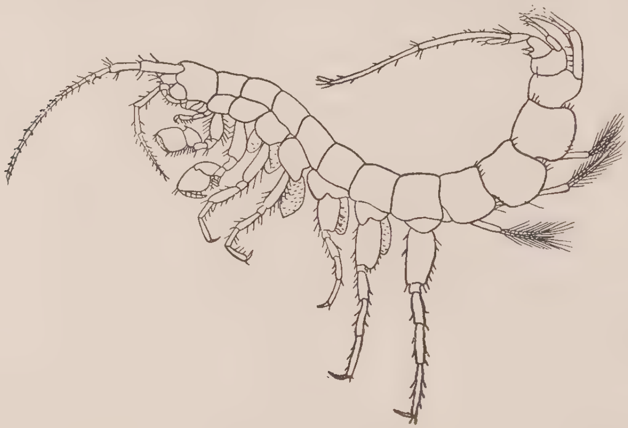

FIG. 281.—The Well Shrimp (*Niphargus aquilex*).—
From Calman, after Wrzesniowski.

earth's crust. Others, such as *Niphargus*, are also found at the bottom of deep lakes, which they are supposed to have reached by similar channels. Near their entrance, subterranean waters often contain members of the above-ground fauna.

(2) The fauna of fresh *surface waters* may be divided into that of rivers and streams, the "rheophile" fauna, and that of lakes and

ponds, the "limnophile" fauna. (*a*) The *rheophile fauna* is for the most part oxygen-loving, and strong swimming or with the habit of taking shelter under or behind stones or of clinging to such objects. Rivers, however, have often backwaters where shelter can be obtained during freshets, and here a more limnophile plankton breeds and furnishes a food supply which passes into the main stream. The rheophile fauna has subfaunas in rapid and sluggish streams, and in springs, where sometimes numbers of the subterranean fauna appear. We have already (p. 28) alluded to the fauna of hot springs. (*b*) The *limnophile fauna* is in less danger from currents than the rheophile, and its smaller members can wander from the bed and banks into the open water. It does not need such strong swimming powers, but has often to exist in a fouler medium. It has different types for lakes, ponds, temporary

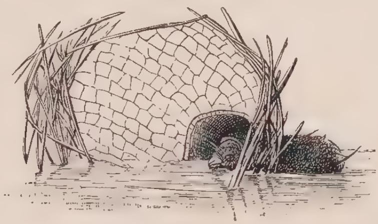

FIG. 232.—The house and snare of a larva of the caddis-fly *Hydropsyche*, with the head of the larva showing. The larva lives in rapid streams and the snare always faces upstream.—From Sharp, after Riley and Howard.

pools whose fauna must consist of animals that can survive drought, marshes, etc.; and in the larger pieces of water possesses a distinct plankton, with plant members, whose function in its economy is the same as those of the marine plankton, and for animals certain of the Protozoa (Heliozoa, Flagellata, Ciliata), Medusæ (in a few tropical lakes), Rotifera, Copepoda, Cladocera, insect larvæ, etc. Fishes and strongly swimming insects form its nekton. The benthos, of molluscs, crustaceans, insect larvæ, worms, protozoa, and sessile organisms, such as *Spongilla*, *Hydra*, and polyzoa, is plentiful in shallow water, where it varies with the amount and kind of the vegetation and the nature of the bottom, but, like that of the sea, becomes more scanty and changes its character in deeper parts. In deep lakes there is a "deep sea" fauna which lives in somewhat the same conditions as those of the abyss of the ocean. It resembles that of the sea in often being blind and sometimes having large eyes, but it is never phosphorescent and it does not differ

greatly from the littoral fauna. Partly it consists of hardy species of the upper regions, partly it is composed of species not found elsewhere. We have already noted how members of the subterranean

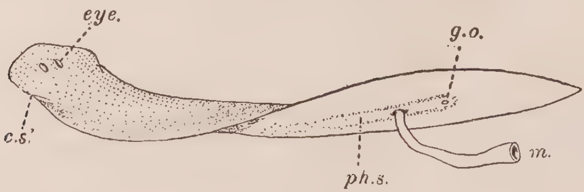

FIG. 283.—A turbellarian (*Planaria polychroa*) swimming.—From Shipley and MacBride.

c.sl., Ciliated slit at side of head; *eye*; *g.o.*, genital opening; *m.*, mouth, at end of outstretched pharynx; *ph.s.*, sheath into which pharynx can be withdrawn.

fauna appear in it. Its benthos is exceedingly scanty, owing to a lack of oxygen, which is brought about by a peculiarity in the circulation of the water. Lakes and ponds have a circulation

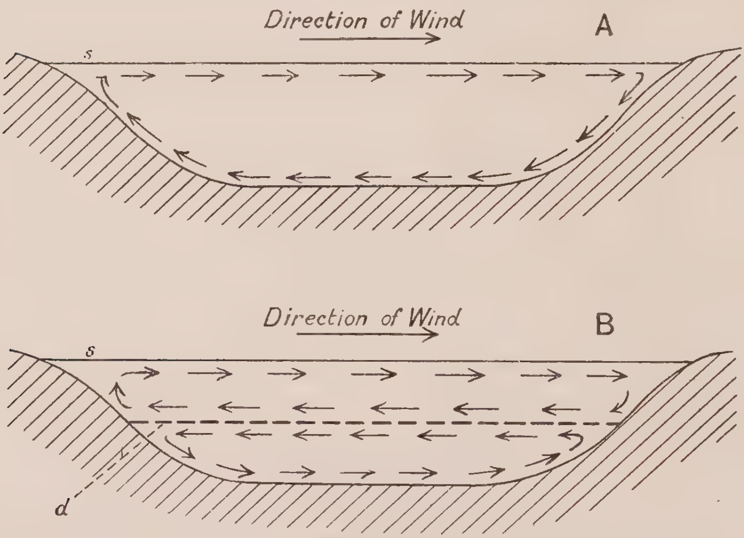

FIG. 284.—Diagrams of the circulation of the water in a lake.

A., when there is no discontinuity layer; *B.*, when that layer is present.
d., Discontinuity layer; *s.*, surface of water.

which is determined by the winds and by differences in temperature. In those which are equal in temperature throughout, it traverses the whole of the water. In them the wind drives the surface water to one side, and to compensate for this a return current

arises, flowing downward upon the leeward shore, across the bottom, and upward upon the other side. Such a circulation exists in very small lakes and during the cold months of the year in deeper lakes. In a lake of unequal temperature the circulation is different. In deep lakes during the warm part of the year the surface waters are heated by the sun and are thereby made so much lighter than those of the depths that the currents set up by the wind can no longer flow to the bottom on their return journey, but set up a superficial circulation, separated from the cold waters below by a "discontinuity layer." Thus the lower layers remain unaerated. When the water cools in autumn the discontinuity layer is gradually lowered till the bottom is reached, and the circulation once more traverses the whole lake.

A special type of lake fauna is that of the *relict seas*. In several

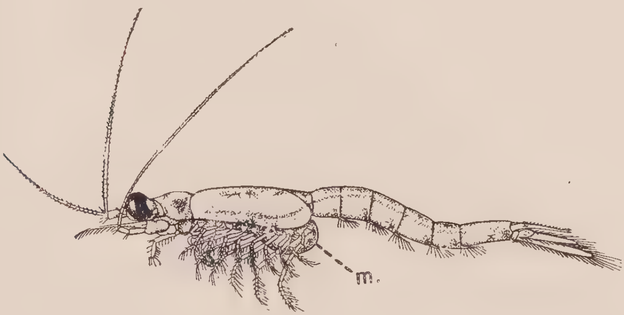

FIG. 285.—*Mysis relicta*.—From Calman.
m., Brood-pouch.

parts of the world, arms of the sea, having been cut off by alterations in the level of the land or by silting up of their entrances, have become, owing to the rivers that flow into them, fresh or brackish lakes. Such pieces of water retain a portion of their marine fauna which has accustomed itself to the altered salinity of the water and now lives in company with true freshwater animals. Relict faunas are found in various lakes in Scandinavia and the adjoining countries. They contain species which are closely related to or identical with others now living in the sea, such as the fish *Cottus quadricornis*, the crustaceans *Mysis relicta*, *Pontoporeia affinis*, *Idotea entomon*, *Limnocalanus macrurus*, etc. In the brackish waters of the Caspian, formerly connected with the ocean through the Black Sea, there live a seal, a herring, and other fishes of marine types, cockles, marine crustaceans (Mysidæ, Cumacea, marine amphipoda, etc.), worms, sponges, and protozoa. It is interesting to

note that of some of these animals, such as the cumaceans and amphipods, there are many peculiar species belonging to genera whose species are not numerous in the sea, which would indicate that the conditions have favoured evolution since separation from the ocean took place. There are other lakes in which a marine, or marine-seeming, fauna is found, but which cannot be discovered ever to have been connected with the sea. Such are Lake Baikal, which has some undoubtedly marine animals whose migration thither is at present a mystery, and Lake Tanganyika, which probably owes the marine appearance of many members of its fauna to a long period of isolation, during which it was more or less brackish, until it became connected with the rest of the African river system.

Here may be mentioned two sets of animals about which it is hard to say whether they are more logically classified independently, as equivalent to the marine and freshwater faunas, or as divisions

FIG. 286.—*Tiphobia horei*, a freshwater operculate snail of marine appearance from Lake Tanganyika. On the left, the operculum.—After Bourguignat.

of the freshwater fauna equivalent to those of subterranean and surface waters. (i) *Brackish waters* are found both in certain of the relict seas, as the Caspian, and on the coast where fresh and salt water meet. Here the fauna consists partly of euryhaline members of the marine and freshwater faunas, and partly of animals which are adapted to a moderate concentration of salts and do not rightly belong to either of these. This is the true brackish water fauna. It consists of such animals as the hydroid zoophyte *Cordylophora*, the jelly-fish *Crambessa*, the brackish water variety of the prawn *Palæmonetes varians*, the bivalve mollusc *Scrobicularia piperata*, various species of such gastropod genera as *Potamides* and *Hydrobia*, etc. As common examples of marine animals which enter brackish waters, the foraminiferan *Polystomella*, the jelly-fish *Aurelia* (Fig. 217), the Shore Crab, the Acorn Barnacle, the Mussel, the Flounder, and the Smelt may be mentioned. It sometimes happens that marine animals of archaic types are more plentiful in brackish waters than

in those of the adjoining seas, as, for instance, the primitive anemone *Edwardsia* in Indian brackish lakes. This is no doubt due to their being more euryhaline than competitors which suppress them in the salt waters. Whether their tolerance of low salinity be, like

FIG. 287.—*Cordylophora lacustris.*

their archaic organization, a survival from earlier ages, when the sea was less salt, is an open question. On the other hand, we may cite as instances of freshwater animals which, in the Baltic and

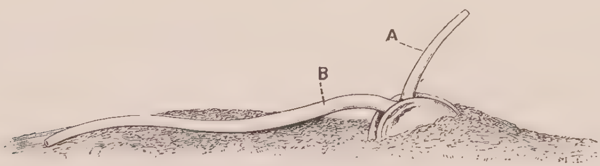

FIG. 288.—*Scrobicularia piperata* in its natural position in the sand. From the *Cambridge Natural History*, after Möbius.

A., Efferent siphon ; *B.*, afferent siphon.

elsewhere, thrive in brackish waters, the flatworm *Microstomum lineare,* the water-fleas *Cyclops quadricornis,* and *Daphnia quadrangula,* freshwater snails of the genus *Limnæa* and mussels of the genera *Anodonta* and *Cyclas,* the Common Eel, the Three-spined Stickleback, and the Miller's Thumb. Since fresh water is

lighter than that of the sea and floats upon it, it often happens in deep coastal waters that a brackish water fauna overlies one that is marine. (ii) *Salt lakes* are, on account of their high salinity, very unfavourable localities for the existence of living beings. The Great Salt Lake of Utah and the Dead Sea are both about five times as salt as the sea. The former contains the water bug *Corixa decolor*, larvæ of flies of the genera *Ephydra* and *Tipula*, and immense

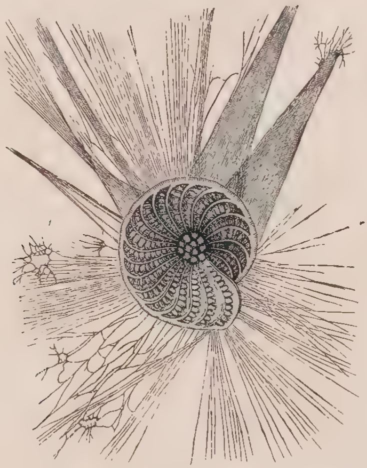

FIG. 289.—*Polystomella*, a foraminiferan which tolerates brackish water. The pseudopodia enclose prey at several points.—From Thomson, after Schultze.

numbers of the Brine Shrimp (*Artemia*). The Dead Sea is said to have no fauna. Other inland salt waters have a fauna which is scanty in proportion to their saltness. It has been divided into three classes—the *haloxene* species, which tolerate saltness, the *halophile* which flourish in it, and the *halobiotic*, such as *Artemia*, which are only exceptionally found in fresher waters. As the water grows salter these classes successively disappear.

CHAPTER XI

THE LAND FAUNA

Regarded as a habitat for animals, the land, for all the luxuriance which its fauna in places attains, is less favourable than the waters. Only in the matter of respiration has it a considerable advantage, because, as we have seen, its medium is more easily moved, contains more oxygen, is not able to carry injurious substances in solution, and is more uniform in composition. Against this stand the disadvantages that on it the indispensable material water can only be obtained at the cost of effort, and is liable to be lost by evaporation; little support is afforded to the bodies of animals; the medium carries less food; and various conditions of life are less equable than in water.

We have noted some properties of water which cause its temperature to vary less and less rapidly than that of the air. A property of air which has important effects upon the constancy of conditions in it is its liability to vary in respect of moisture, that is of humidity, cloud, and rainfall. This is not only one of the factors that govern the temperature of the air itself, but also affects the extent to which the sun's rays reach bodies in it: the loss of heat from animal bodies by radiation and evaporation; their loss of water by evaporation; and the growth of plant food. All these are matters of the first importance to animals. Other variable conditions of the atmosphere are pressure and movement. The extreme effect of variation in atmospheric pressure is seen in "mountain sickness." With a low pressure, the tension both of oxygen and of carbon dioxide in the lungs is, of course, lowered. The lowering of the tension of oxygen makes necessary more active movements of respiration. But the action of the nervous centre by which these movements are regulated is tuned by the acidity of the blood caused by the presence of carbonic acid; and the effect of a lower pressure of carbon dioxide in the lungs is to lower that acidity and thus to lessen rather than to increase the activity of the muscles of respiration. The animal, therefore, suffers from lack of oxygen. In Man there occur nausea and vomiting, lack of appetite, intestinal dis-

turbance, headache, fainting, blueness of lips and face, laboured breathing after the least exertion, difficulty in mental effort, and disturbances of behaviour like those of intoxication with alcohol. After a time, however, the body becomes acclimatized. This is brought about by an increased acidity of the blood due to non-volatile acids, and an increase in the number of the red blood corpuscles. Though variability in the amount and direction of the movements of the air has not for animals the importance that it would have if air were as heavy as water, yet it is far from negligible for those that fly.

These variations in physical conditions, together with some others, such as those of the electrical phenomena, which have less influence on life, taking place from time to time in every locality, constitute weather and characterize the seasons. Those which exist between one place and another make up *climate*. Differences in temperature, light, pressure, and movement of the medium exist between localities under water, but since these differences of temperature, which are the most important for animal life, are comparatively slight, and differences in moisture, the other essential factor in climate, are impossible, it cannot be said that true climate exists for water animals. Were the amount of heat and light received from the sun the only factor concerned, climate would differ in a regular manner from the equator to the poles, with the duration of sunlight and the angle at which the rays fall upon the earth ; but since moisture and pressure are also of account, the irregular configuration of the land, varying the altitude and the nearness to expanses of water, makes the distribution of climate extremely irregular. The true boundaries between the familiar torrid, temperate, and polar belts do not coincide with lines of latitude ; in each of them extremes of temperature are greater in a locality according to its distance from the sea, whence the so-called "continental climate" ; and within each there may be distinguished climatic types—as those of the coasts, plains, deserts, and mountains—which have affinities with those of corresponding localities in other belts. Besides their characteristic temperature and illumination, the temperate zones are distinguished from the others by more variable weather. The greater part of the land surface of the globe lies in the North Temperate Belt.

We may state the characteristics of the land fauna in terms which correspond to those which we applied to the fauna of the water. It is, on the whole, eurythermal, and sometimes it is warm-blooded ; its protoplasm is not exposed naked to the medium, but is almost invariably protected from evaporation and changes of temperature

by stout coverings of various kinds;[1] its skeletons are strong; it has no special swimming organs, though some of its members can swim; it is never fixed; its breathing organs are adapted to

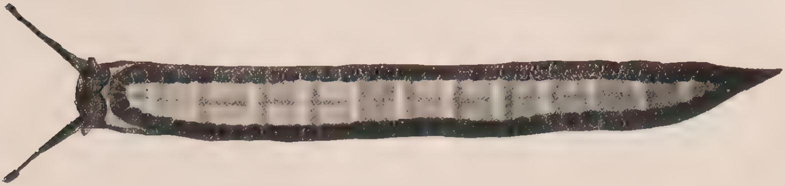

FIG. 290.—The sole of the foot of a crawling slug, showing waves of contraction.—From Taylor.

the use of air, generally by drawing it in and out of some kind of chamber; and its gametes are not set free before fertilization.

The modes of locomotion of land animals, though they do not

FIG. 291.—The Common Starfish (*Asterias rubens*), using its tube feet.

differ essentially from certain of those which are used in the water, present some interesting developments. Perhaps because it needs a stouter skeleton than is usually present in members of the benthos,

[1] In land planarians, nemertines, and slugs there is only a pellicle. Such animals live only where the air is humid.

perhaps because of the nature of the ground, *walking* is much commoner on land than in the sea. Over *crawling* movements, such as those of snails and slugs, of worms and starfishes, etc., in

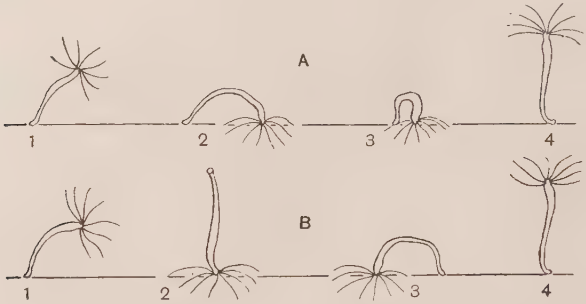

FIG. 292.—Diagrams of *Hydra* in the successive positions of two modes of "walking."
A., Looping; *B*., somersaulting.

which a wide surface is applied to the substratum and dragged across it by its own contractions or the movements of limbs, *true walking* has the advantage of losing less power by friction; and this

FIG. 293.—Diagram of the positions assumed by a man in walking. Read from left to right.—From Schäfer's *Physiology*, after Marey.

is important in air, where the body is relatively heavier; but it is less easy on a very soft surface, such as an under-water substratum often has, than on the harder land surfaces. Nevertheless, insects and the higher crustaceans walk under water, sea-urchins pole themselves

along with their spines in a similar way, leeches and *Hydra* progress by raising their bodies into loops, and even certain whelks use their foot in a looping manner. Like paired fins, limbs work as levers,

FIG. 294.—A man in the successive positions of walking.—From Marey.

but they are compound levers, composed of several segments jointed together, and thus they are the better able to raise the body above the ground, and can execute more complicated movements. Essen-

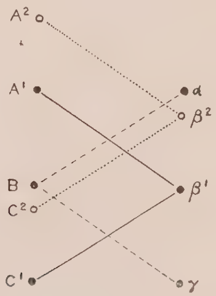

FIG. 295.—A diagram of the walk of an insect.

The dark dots represent the points at which the feet rest on the ground; the light dots represent the second position of one of the two sets in which the feet are moved.

A^1., β^1., C^1., represent respectively the first left-foot, the second right foot, and the third left foot. These three work together. A^2., β^2., C^2. represent their second position. α., B., γ. represent the alternate set. While either of these sets is being moved, the body rests upon the tripod formed by the other.

tially, their mode of working is as follows: Certain of the limbs, being straightened, raise the body and tilt it onwards; then others, kept bent, partly moved by muscles, partly, and in the best walking largely, by the mere effect of gravity, swing forwards and take up a

position in front of those that have remained upon the ground; lastly these straighten while the others are bent and swing forwards in turn. In animals which walk upon two legs, these act alternately. In four-legged animals the near foreleg and the off hind leg work together,[1] and *vice versa*. In insects the first and third leg of one side form a set with the middle leg of the opposite side. In animals with a greater number of legs the action is more complicated, but the principle is generally the same.[2] At the end of each leg there is usually a foot—a part which is broader than the region above it and in other ways, as by being padded or having a hoof,

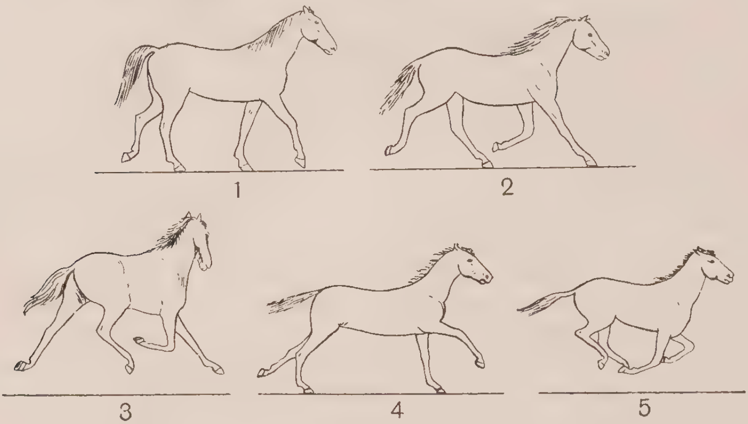

FIG. 296.—Various paces of the Horse.—From Pettigrew.

1, Walking; 2, slow trotting; 3, fast trotting; 4, 5, galloping.

adapted to being applied to the ground. The feet of animals which live upon soft ground are broader than those which are used upon a harder surface, as those of a hippopotamus are broader than those of a horse; and feet are often adapted to other purposes besides progression, as by being webbed to swimming, or by possessing claws, or toes that can meet, to seizing food. Running is a kind of walking in which the action of the limbs is so swift that for a short time they are all off the ground at the same time. This may be seen in the swift trotting and galloping of horses. In leaping and hopping, some of the limbs, usually the hinder

[1] In "ambling," the action of the Elephant, Giraffe, and Camel, the two legs of each side move together.

[2] In *Peripatus* and the Millipedes the two legs of a pair move together, resembling thus the parapodia of worms rather than the legs of other arthropods.

pair, are suddenly straightened so as to throw the body into the air. The limbs which are thus used are powerful and often of great length, as in the Frog and Jerboa (Fig. 334). Leaping may also

Fig. 297.—The Common Frog, showing the hind limbs which are straightened in leaping.

be performed without the aid of paired limbs, as in some molluscs, such as the Glass Snail (*Vitrina*, Fig. 19) and the Cockle, which

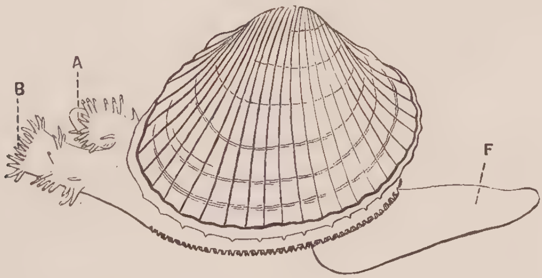

Fig. 298.—The Common Cockle (*Cardium edule*).—From Cooke, after Möbius.

A., Efferent siphon; *B.*, afferent siphon; *F.*, foot, used in leaping.

suddenly and violently straighten the foot. The legs of vertebrata show a series of stages of perfection. In the Newts, still imperfectly adapted to land life, they are spread out at the side of the body and

hardly raise it. Frogs and toads are, of course, leaping animals. Reptiles show no great advance upon newts, but it is said that some

Fig. 299.—A newt walking.
The animal uses the foreleg of one side with the hind leg of the other, and does not raise the belly from the ground.

lizards and crocodiles in swift walking straighten the limbs and bring them under the body so as to raise it. A few lizards, as the

Fig. 300.—The Sand Lizard (*Lacerta agilis*), walking with the belly not raised from the ground.

Frilled Lizard (*Chlamydosaurus kingi*) of Australia, run upon their hind legs. Others, and the snakes, which are closely related to

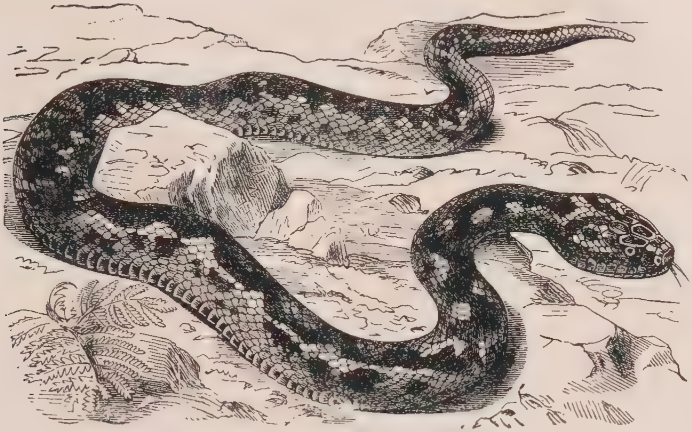

FIG. 301.—The Viper (*Pelias berus*).
Note the large scales of the belly, which are moved by the ribs and used in crawling.

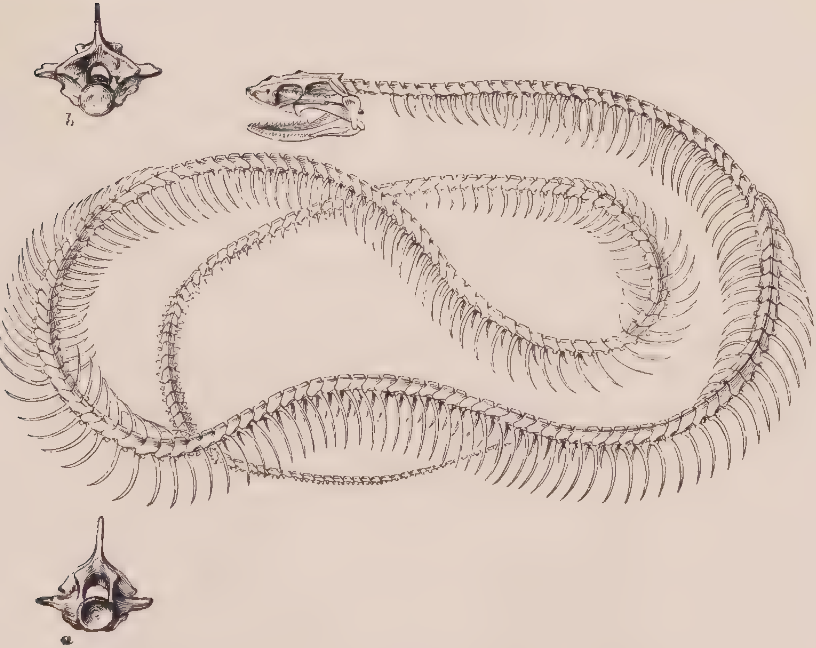

FIG. 302.—The skeleton of a snake.—From *Cassell's Natural History*.

a., Anterior, and *b.*, posterior faces of a vertebra of a snake, showing the knobs and hollows by which the vertebræ interlock, so that the backbone is enabled to bear the strain which is put upon it in crawling.

them, have lost their limbs and relapsed into crawling, which they do by scraping upon the ground with scales attached to the ends of the ribs. Certain extinct reptiles, however (*Theromorpha*), stood up well upon their legs, as do the Mammals. In the mammals there is a series,[1] from "plantigrade" forms, such as Man and bears, which place the whole of the sole upon the ground, through "sub-plantigrade" animals, such as the rabbit, which run upon the toes but when at rest apply the whole sole, and "digitigrade" animals, like dogs and cats, which use only the under surface of the toes;

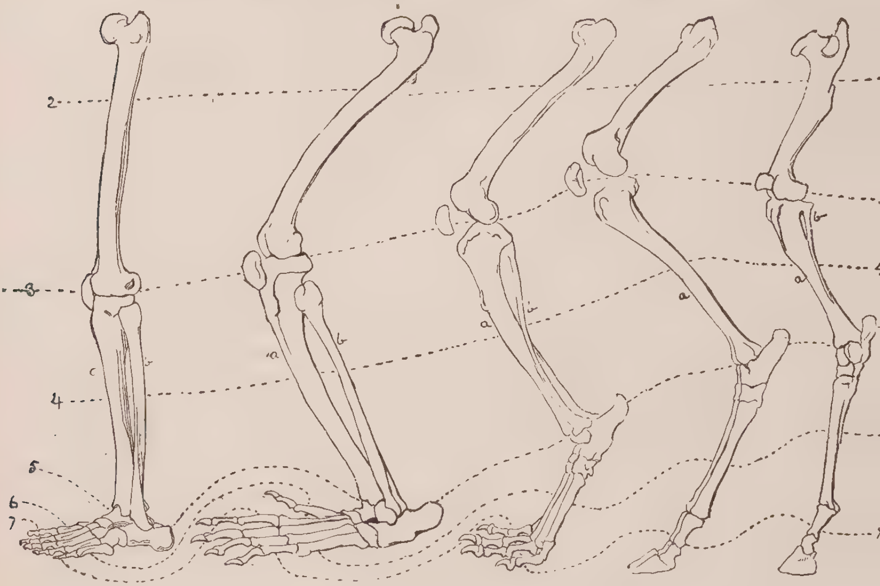

FIG. 303.—The bones of the hind limb of Man, compared with those of a monkey, dog, sheep, and horse.—From Romanes, after Le Conte.

to those which are "unguligrade" and walk only upon the tips of the toes, as do the Ungulata. Among ungulates, again, the series runs from five-toed animals like the Elephant, through pigs, with four toes, to two-toed forms such as cattle and camels, or through tapirs and rhinoceroses to one-toed forms, such as the Horse. Here we have the leg in perfection as an organ for travelling over firm grounds.

Climbing is practised by water animals as well as by those of the land, but for the latter it involves more effort than for the

[1] Needless to say, the examples here quoted do not represent an evolutionary series.

former, and among them organization for it is accordingly more elaborate. Some animals, especially those which crawl, such as

Fig. 304.—Bones of the fore-feet of Ungulates, showing in two series adaptation to swift running on hard ground.—From Romanes.

A.-D., The series in which the foot is symmetrical about the middle digit (perissodactyle). *A.*, Elephant ; *B.*, Hyrax ; *C.*, Rhinoceros ; *D.*, Horse.

E.-H., The series in which the foot is symmetrical about two toes (artiodactyle). *E.*, Hippopotamus ; *F.*, Pig : G., Deer ; *H.*, Camel.

starfishes and snails, climb by the same organs by which they progress upon the level, having them little if at all modified for the

purpose, and using them in much the same way. Others have special climbing organs, though these are usually modifications of those which are used in walking. Such modifications may enable the animal to grasp relatively large objects, to hang by hooks from

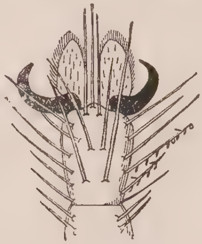

FIG. 305.—A semi-diagrammatic view of the foot of a fly, showing hooks and adhesive pads. Two of the hairs are represented as bearing bacteria, which the animal distributes in this way.—From Shipley.

roughened or soft surfaces, or to adhere by suckers to surfaces that are smooth. They are usually borne on paired limbs, which are often very long and slender. Many insects, such as flies and bees, have at the end of each leg a pair of strong, hooked claws and a

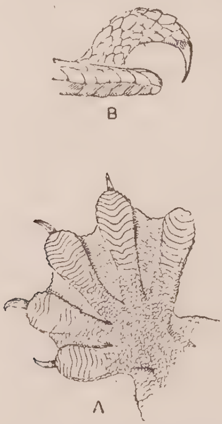

FIG. 306.—The right fore-foot of the gecko *Ptychozoon homalocephalum*.—From Gadow.

A., The sole, showing the ridges which the pressing down of the foot causes to spread so that when the pressure is relaxed and they return to their original position, vacua are produced and the toes act like suckers; *B.*, a side view of a digit.

simple or double pad (*pulvillus*), made sticky by a secretion, and these organs are used alternatively. Crustacea, such as spider crabs and the amphipod *Caprella*, use slender legs, whose last joints are often hooked, and pincers. Among fishes, the Jumping Fish (*Periophthalmus*, Fig. 322) and the Climbing Perch (*Anabas*), use

FIG. 307.—Diagrams to show the structure of the wings in the three classes of pentadactyle vertebrates which possess those organs.—From Romanes.

their strong pectoral fins. Tree frogs have suckers at the ends of their toes. Snakes climb partly as they crawl (p. 278) and partly by grasping boughs with their bodies, and especially with their tails. Chameleons have hands with opposable fingers on both pairs of limbs. Geckos have sucker-like pads at the ends of their digits. Climbing birds, such as parrots and woodpeckers, grasp boughs with their toes, which are turned in two pairs in opposite directions, and cling to the bark with hooked claws. Parrots, of course, use also their beaks. Many mammals climb, either hooking hands or feet over the boughs, like sloths (Fig. 79), and some thumbless monkeys, or grasping with opposed digits or with the tail, which is prehensile in members of a number of different orders. Sometimes, as in the Tarsier and certain bats, there are suckers on hands or toes.

Flight is for land animals what swimming is for the water fauna. By it they support themselves and travel through the medium as a fish does by the use of its tail. Only, since the medium is so much thinner than water, the organs of flight must be placed where they can not only cause the body to travel forwards but also support it, and accordingly they stand where in the fish the raising and balancing organs—the pectoral and often the advanced pelvic fins—are situated. Thus, instead of a single propeller placed astern, flying animals have two propellers (or perhaps since, as we shall see, in flight they are turned forwards, they should be called tractors), placed at the greatest breadth of beam. We have already seen that the wings of insects are folds of the skin of the back, but those of vertebrate animals are the fore limbs. In birds, the surface which beats the air is principally composed of feathers; in bats it is skin, as it was in pterodactyles. The different ways in which the skeleton of the limb upholds the wing are shown in Fig. 307. Alike in insects, bats, and birds, each wing is roughly triangular, tapering outwards; is stouter in front, where it cuts the air, than behind; and, in the normal extended position, is not flat, but concave below and convex above, with the concavity turned a little backwards. At each stroke the wing beats downwards and forwards, being at the same time twisted on its axis, so that it takes on a spiral curve, like that of a screw. In the upstroke this motion is reversed. Thus, like the organs used in swimming, it presents a concave biting surface to the medium in the efficient stroke and a convex surface in the non-efficient stroke. Moreover, the wings of birds and bats are partly folded as they are drawn up, and extended as they beat downwards, and thus, like swimming organs, offer less surface to the

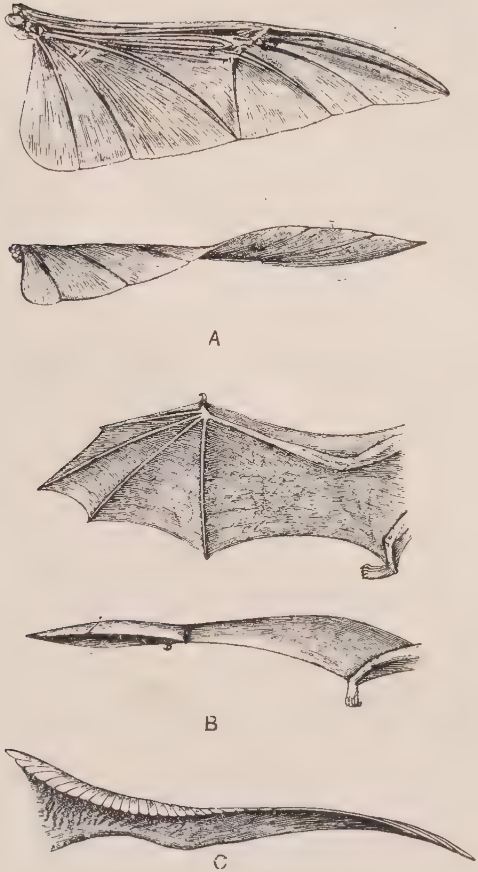

FIG. 308.—Wings.—From Pettigrew.

A., The right wing of a beetle (*Goliathus micans*), seen from above and from behind; *B.*, the right wing of a bat, seen from below and from behind; *C.*, the right wing of a bird, seen from behind.

All the wings are fully extended.

FIG. 309.—A pigeon in flight, with the wings coming down.—From Marey.

medium in the non-effective than in the effective stroke. The raising of the wings above the body is helped by the falling of the latter in the interval between the downstrokes. If the wing were flat and beat simply downwards, it would tend only to raise the body. But being concave, with the concavity backward as well as downward, it drives the body forward as well as sustaining it. Moreover, since it strikes forwards, and has a spiral curvature, its tip, moving from above downwards, from behind forwards, and from without inwards, lays hold of the air with its concave surface and forces it along the spiral groove formed by the under surface of the

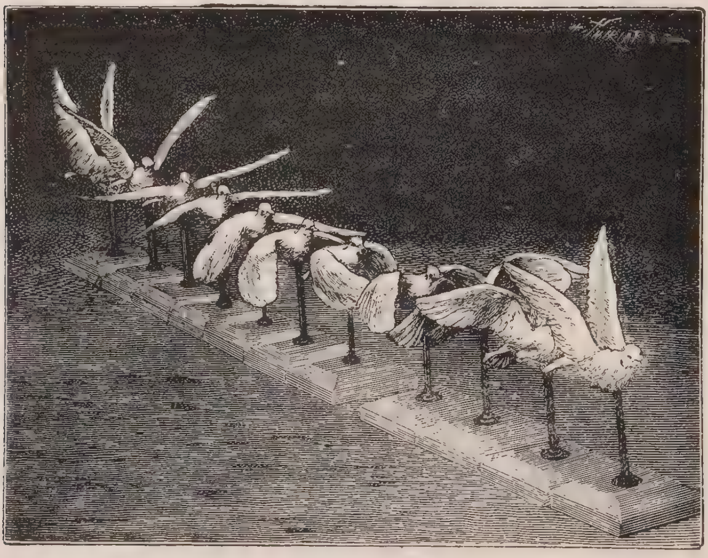

Fig. 310.—Pigeons in successive positions of flight.—From Marey.

wing to the root of the limb, where it escapes backwards over a convex surface. The upward or downward direction of flight is regulated by altering the direction of the beat. Steering is effected in the same way and by spreading out the feathers of the tail, which both acts as a rudder and also assists in checking the flight in alighting. Birds can also glide through the air using the wings as motionless planes, and, probably by taking advantage of air currents, many are able to soar to a height in a spiral course, with the wings outspread but apparently not moving. Besides the animals that truly fly by the movement of wings, there are others that can glide through the air for

FIG. 311.—A pigeon using its tail in steering.—From Pettigrew.

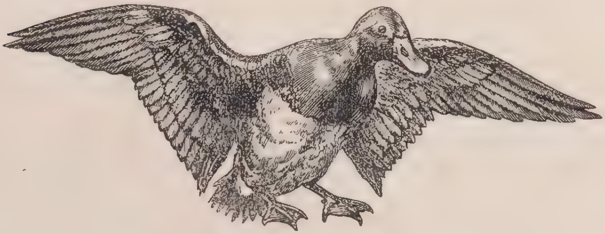

FIG. 312.—A duck checking its way with wings and tail as it alights on the water.—From Pettigrew.

FIG. 313.—The Colugo (*Galeopithecus*).

considerable distances by using folds of skin. Such are the Colugo (*Galeopithecus*) of South-east Asia, the Flying Squirrels of Europe, America, and Africa (*Pteromys*, *Sciuropterus*, and *Anomalurus*), and the Flying Phalangers of Australia (*Petaurus*, etc.), all of which have skin-folds which stretch from the forelimb to the hind limb of each side and can be spread by expanding the limbs ; certain East Indian lizards, such as the Flying Dragon (*Draco volans*), which have folds on the flanks ; and the Australian Flying Spider (*Attus volans*), whose parachutes are extensible flaps of the abdomen. We have already alluded to the gossamer flight of young spiders. The Fying Fishes (*Exocœtus*, Fig. 253) have very large pectoral fins which support them in the air, and it has been claimed, but not proved, that they use these as true wings. Certainly they start

FIG. 314.—The Flying Phalanger (*Petaurus*).

their " flight " by a leap from the water effected by a powerful stroke of the tail, whose fin, having the lower blade longer than the upper, is perhaps on that account more easily able to drive them out of the water.

Though the land fauna is exceedingly varied, it is derived from a smaller number of the great groups of animals than is that of the water. Protozoa do not stray from the moisture of the soil, where they might almost be said to live in the last microscopic ramifications of the freshwater system. Other groups which are unprovided with a skin or cuticle, such as the Cœlenterata and Echinodermata, are absent. So are all the groups of sessile animals. Fishes are, of course, wanting, since their organization is unfit for any land life beyond, at best, a barely amphibious existence. Of Mollusca only the Snails and Slugs are found, though these are numerous.

Certain flatworms and leeches and the earthworms have established themselves where the conditions are suitable. Various crustacea—crabs, hermit crabs, amphipods, isopods (woodlice), etc.—show the hardiness of the organization of their group by existing but little altered in this foreign habitat. But by far the most varied and successful part of the fauna is composed of two groups, the collection of unrelated classes of arthropoda known as the Tracheata from their common possession of air tubes in the body, and the higher

FIG. 315.—The Flying Lizard (*Draco volans*).—From Gadow.

Vertebrata, under which term may be included all those classes—Amphibia, Reptilia, Aves, and Mammalia—which have lungs and pentadactyle limbs.

The land fauna, like that of the water, may be divided into subordinate faunas in more ways than one. A classification, according to the vertical position of the habitat, would recognize in any locality an *aerial* fauna, which spends much of its time in the air, a *plant-borne* fauna (where plants exist), a *ground-surface* fauna, a *cryptozoic* fauna, and an *underground* or *soil* fauna. An animal may, of course, belong to more than one of these sets.

The characteristic modes of locomotion of their members are respectively flying, climbing, walking, crawling, and burrowing,

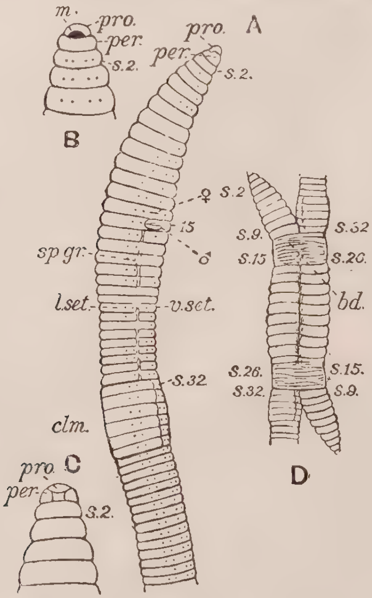

FIG. 316.—The Earthworm, *Lumbricus.*

A., The forepart of the body, from the right side ; *B.*, the head from below ; *C.*, the head from above ; *D.*, two worms in sexual congress.

bd., band of mucus by which the worms are held together ; *clm.*, clitellum ; *l.set.*, lateral setæ ; *m.*, mouth ; *per.*, peristomium ; pro., prostomium ; *s.*2–*s.*32, segments ; *sp.gr.*, groove along which the sperm passes from the male opening on the 15th segment of each worm to the spermathecæ on the 9th and 10th segments of the other ; *v.set.*, ventral setæ ; ♂ male opening ; ♀ female opening.

Note : (1) Adaptation to burrowing, seen in the cylindrical body without projecting limbs or highly developed sense organs on the head (compare *Nereis*, Figs. 356, 362) ; (2) arrangements for reciprocal impregnation.

FIG. 317.—The Common Seal (*Phoca vitulina*).—From Parker and Haswell.

and something has already been said about each of them under these and other heads. We shall here regard land animals in

another way, namely, as constituting faunas according to the types of locality they inhabit.

FIG. 318.—The King Penguin (*Apterodytes longirostris*) in three positions of swimming.—From Pettigrew.

The first of these faunas of the land is one that only partly belongs to it. Where it meets the sea, and again upon the banks of fresh

waters, there dwells a set of *amphibious* animals, which comes partly of land stocks and partly of groups that belong to the water. By their habits these inhabitants of the borderland

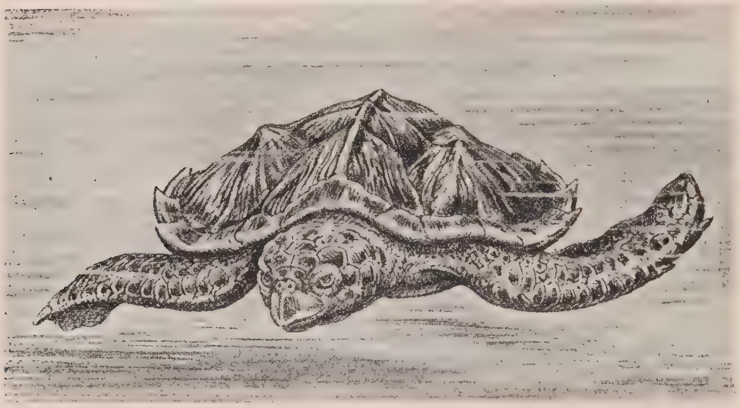

FIG. 319.—The Hawksbill Turtle (*Chelone imbricata*) swimming.—From Pettigrew, after Mützel.

Note the spiral twist of the paddles, which are used something after the manner of the wings of a bird (see p. 284).

merge, on the one hand, into the rest of the land fauna, and, on the other, into that of the water, so that it is impossible to draw sharp distinctions between the three sets of animals ; but the amphibious fauna may be defined as consisting of animals of either element

FIG. 320.—Amphibious beetles of the seashore.—From Furneaux.
1, *Æpys marinus* ; 2, *Micralymma brevipenne.*

which are at home in the other, yet by breeding or hunting in their original home maintain their connection with it. Thus an animal of land ancestry is counted to belong to the water only when, like the whales, it breeds there, and land-haunting animals of a water stock, if they breed in the water, are only accounted to the

amphibious fauna, however terrestral be their life in other respects. As examples of the land and sea amphibious fauna, we may mention the following. Of land descent are: seals, the most completely aquatic of all amphibious mammalia, with a propeller formed by

Fig. 321.—*Onchidium tonganum.*—From Semper.

the back-turned feet, yet breeding on land (Fig. 317); the Sea Otter; the Polar Bear; penguins; turtles; various insects, as the bug *Æpophilus*, the spring-tail *Anurida*, the beetle *Æpys*, etc.; the spider *Desis* of the tropics, whose habits resemble those of the water

Fig. 322.—The Jumping Fish (*Periophthalmus kœlreuteri*).—From Moseley.

spider (*Argyroneta*) of British fresh waters; the slug, *Onchidium*, and some earthworms (*Pontodrilus*, etc.). Of marine descent, besides certain members of the fauna in temperate parts of the globe, such as some of the periwinkles, there is a remarkable series of animals in warm countries. The little Jumping Fish (*Periophthalmus*) is a "bull-head," found on mud-flats and other shores in

the tropics, whose goggle eyes enable it to survey its unusual habitat; its vascular tail, dipped into the water, to breathe; and its fore-fins, bent at an elbow, to spring into the air and catch a

FIG. 323.—The Robber Crab (*Birgus latro*).—From Calman.

fly on the wing, or to hunt for crabs and for *Onchidium*. A number of large crustaceans must be classed here, though some of them spend most of their time at a very considerable distance from the

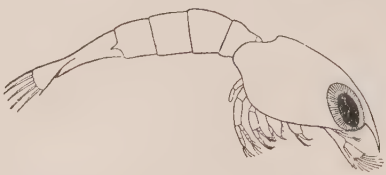

FIG. 324.—The marine larva of the Robber Crab.
That of *Cœnobita* is very similar.

water. Among these are the Fiddler Crab (*Gelasimus*), already mentioned (p. 163), which makes burrows in mud or sand-flats in the tropics; *Ocypode*, also a burrower, which runs swiftly over tropical beaches and the adjacent land; the Land Crabs (*Gecarcinus*), which, though they live far from the sea, return thither to

hatch out their young; the Robber Crab (*Birgus latro*), a great hermit crab which climbs palm trees, breaks open and eats cocoanuts, and having an armoured abdomen is able to dispense with

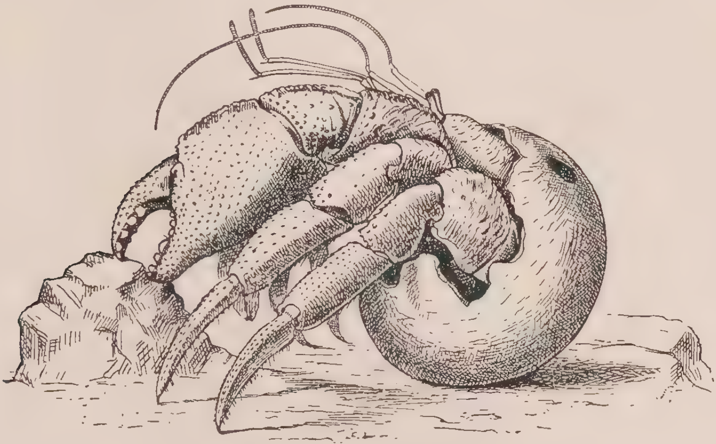

FIG. 325.—*Cœnobita perlatus*, one of the Land Hermit Crabs, using the shell of a cocoanut which has been emptied and cast away by Man.

a shell; the smaller hermit crabs of the genus *Cœnobita*, which require shells but will adopt such substitutes as the cast away shell of a small cocoanut, certain crayfishes, and the strange,

FIG. 326.—The Common Otter (*Lutra vulgaris*).—From Beddard. Note the webbed feet and the strong tail, used in swimming.

lobster-like, burrowing *Thalassina*. Examples of the land and freshwater amphibious fauna of land descent are: various mammals, as the Duckmole (*Ornithorhynchus*, Fig. 379), Otters,

Beavers, Water Voles, and Hippopotamus; Crocodiles; Turtles; certain snakes; snails, such as *Succinea*; various insects, including some of those whose breathing arrangements we have already described; the Water Spider (*Argyroneta*); and various earthworms (*Enchytrœidæ*). Of water descent are: the Amphibia, except some newts which do not leave the water (as *Proteus*, already mentioned (Fig. 22), and *Siren*, the American "Mud Eel") and some frogs which breed on land, as we have already seen; the Climbing Perches (*Anabas*) of Africa and the East Indies, which scramble over land with their pectoral fins and

FIG. 327.—The Beaver (*Castor fiber*).—From Pettigrew.
The hind feet and the tail are more strongly adapted to swimming than those of the Otter.

are said to be able to climb trees; gastropod molluscs such as *Navicella*; and crabs such as some species of *Telphusa* and *Sesarma*. Naturally, the amphibious fauna is adapted to make the best of both worlds. Many of the land-descended vertebrata have webbed feet, or broad flat tails, or both, for swimming and steering. Of those whose tails are small or absent, frogs and seals use the hind feet only, though in very different fashion. Turtles, whose limbs are converted into flippers, use both pairs. Penguins (Fig. 318), whose feet are webbed, the wings flippers, and the feathers almost converted into scales, use the wings for swimming under water and the feet for steering and surface swimming. Of the tailed species, some,

as the Water Shrew, use the tail for swimming and the feet only to assist in steering. Others, as the Water Opossum, swim with the feet and steer with the tail. Others, as the Otter, use both tail and feet for swimming, the former for rapid swimming, the latter

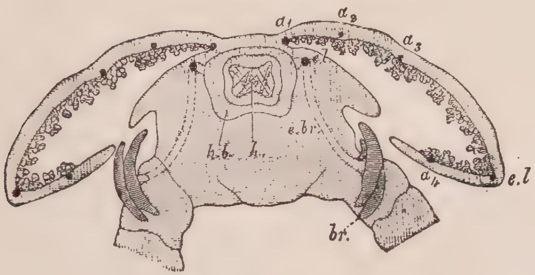

FIG. 328.—A diagram of a transverse section of the thorax of the Robber Crab, showing the gill-chambers converted into lungs, the vascular tufts of their lining, the gills, and the principal blood vessels.—From Semper.

*a*1–*a*4, Afferent vessels of the lung; *br.*, gills; *e.br.*, efferent vessels of the gills; *e.l.*, efferent vessel of the lung; *h.*, heart; *hb.*, pericardium.

for paddling. In amphibious mammals the body is usually shaped for swimming, ear-flaps are reduced, the "whiskers" are strong, to resist the water, and the fur has special qualities. Amphibious animals of water descent acquire means of breathing air. Molluscs

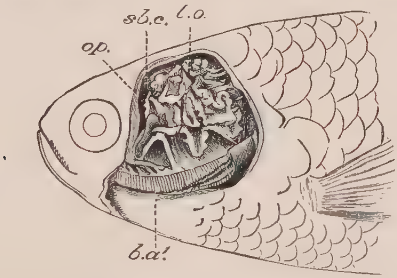

FIG. 229.—The head of *Anabas scandens*, one of the Climbing Perches, with the gill cover removed to show the arrangements for breathing air.—From Bridge.

b.a'., First branchial arch; *l.o.*, "labyrinthine" organ; *o.p.*, base of operculum; *sb.c.*, supra-branchial cavity.

use the mantle chamber as a lung. Crabs draw air through their gill-chamber, whose walls are specially vascular; in the Robber Crab the gills are much reduced, and vascular tufts are developed upon the wall of the chamber. In the Climbing Perch the gill

cavity is enlarged, and contains a "labyrinthine organ" composed of vascular folds of the fourth branchial arch.

The completely terrestrial faunas are many, in correspondence with the great variety of conditions which, as we have seen, is a characteristic of the land. We shall only allude to some of the more striking of them. Above the amphibious fauna comes one which, though it cannot be said to live in the water for periods of time that are considerable, has business with it, and in many cases enters it occasionally. To this *coast and bank fauna* belong the water birds, both swimmers and waders; such crustaceans as the Shore Slater (*Ligia oceanica*) and the sandhopper *Talitrus*;

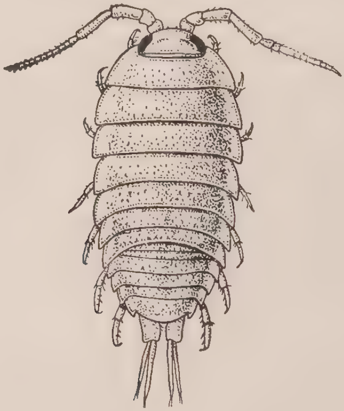

FIG. 330.—The Shore Slater (*Ligia oceanica*).—From Calman, after Sars.

and the adults of various insects whose larvæ live in the water. Many of these animals have a very wide distribution. Farther inland are the faunas of the plains, forests, mountains, snowlands, and deserts. In these, while the burrowing and cryptozoic subfaunas have no very distinctive features beyond the adaptation to varying degrees of moisture, the visible and familiar animals are highly characteristic. Needless to say, the peculiarities of each of them vary with latitude, and it would be possible to classify them thus, taking the polar, temperate, subtropical, and tropical belts, and in each of these distinguishing between the faunas of the plains, forests, etc. But since, of the characters by which animals are adapted to their present circumstances, those which correspond with the type of locality are more important and conspicuous than those which vary with latitude, we shall not adopt that course.

On the *plains* the animals have keen sight, and smell, and

hearing, and feet of the types which we have described as adapted to swift running—digitigrade and unguligrade, with great reduction of the toes, but not prehensile. Horses, asses, zebras, antelopes, cattle, ostriches, the Great Kangaroo, the Cheeta (Fig. 97), and cer-

FIG. 331.—Animals of the South African Veldt, members of a plain fauna.

tain races of wolves are characteristic members of this fauna. In *deserts* there is a fauna which has features of its own added to those of the plain fauna, into which it shades upon the dry prairies. The conditions of life which are characteristic of deserts are: scarcity of water, great variations of temperature, from day to night as well

FIG. 332.—The Arabian Camel (*Camelus dromedarius*). Though this animal has only two toes, its feet are broadened for use upon shifting sand. See Fig. 304, *H*.

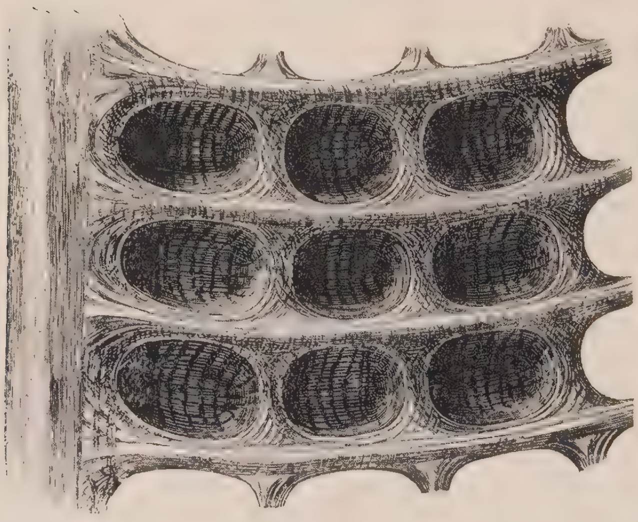

FIG. 333.—A portion of the region of the wall of the Camel's stomach, which is provided with cells for storing water.—From *Cassell's Natural History*.

as seasonal, because of the radiation in the dry air, the presence of much sand and dust, and poverty of vegetation, much of which is spiny and hard to feed upon. We find consequently in the desert fauna: (i) an almost universal sandy colour of various shades and patterns; (ii) the power of enduring for a long while without drinking—the well-known water-storing arrangement of the camel's stomach is an adaptation to this end; (iii) that the nostrils can be closed, so as to keep out the dust; (iv) in reptiles, the habit of burying themselves in the sand as a protection against the cold at night and when they are pursued; (v) sometimes, as in camels and some lizards, broad feet for walking on the shifting sand; (vi) a swiftness and alertness which, as has been said, they share with the inhabitants of the plains, and which in some rodents, such as the Jerboas (*Dipus*) and the Jumping Hares (*Pedetes*),

FIG. 334.—The Jerboa (*Dipus hirtipes*).—From Beddard.

is attained by the development of the power of leaping. As usual this is gained by a great elongation of the hind legs. Life in the desert is hard, and the fauna is a scanty one. The great deserts of the world lie (1) in a belt across North Africa and Mid-Asia, from the Sahara to the Gobi Desert; (2) in South-West Africa, including the Kalahari Desert; (3) in Central Australia; in the south-west of the United States, including the Salt Lake Desert and those of Arizona and Colorado; (5) in Patagonia and Argentina, and as a strip along the coast of Chile. Deserts do not always resemble the plains in being level ground, nor are they always completely covered with sand. In places they are rocky, or even mountainous.

Snowlands, like deserts, may be flat or hilly. They may also be permanent or exist only in winter. They have usually a seasonal flora in the summer. The milder of them may have a permanent vegetation of conifers, and thus merge into the forest lands of the

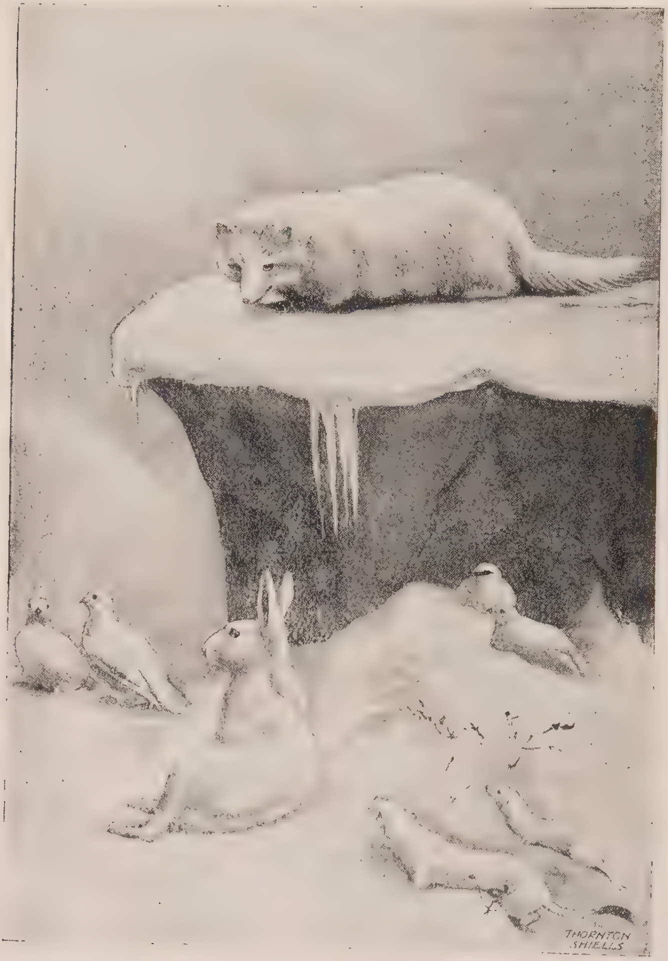

FIG. 335.—Members of a snow fauna.

An example of the possession, by a group of different animals living in the same locality, of common features, which enable them to support life there. Note the thick, white clothing, which keeps them warm and renders them inconspicuous. The animals shown, which are drawn from an exhibit in the British Museum (Natural History), are the Arctic fox, Stoat or Ermine, Weasel, Mountain hare, Willow grouse, and Ptarmigan. They come from the south of Norway, and assume this covering in winter. Others, such as the Polar bear, Snowy owl, and Greenland falcon, living amid perpetual snows, are clad in the same way all the year round.

cooler parts of the temperate zone: in the colder of them the permanent flora consists mainly of mosses and lichens. The snow-

FIG. 336.—The Musk Ox (*Ovibos moschatus*).—From Flower and Lydekker.

land fauna is composed partly of animals peculiar to it, but largely of species that range into milder climates. It is, of course, capable

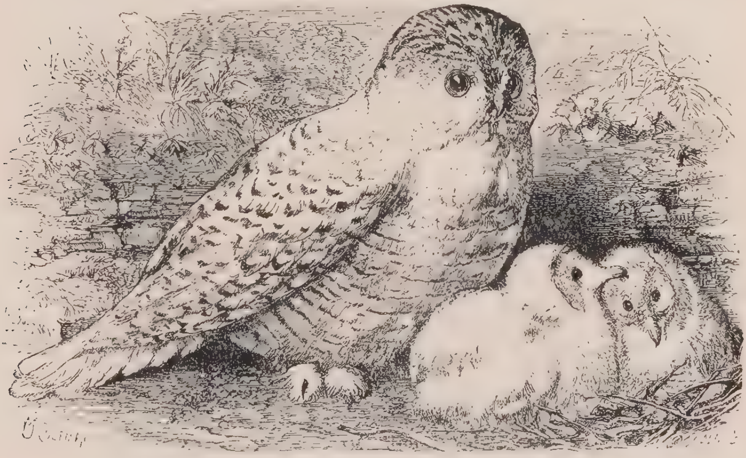

FIG. 337.—The Snowy Owl (*Nyctea scandiaca*).

of standing great cold; often it hibernates. Its warm-blooded members have thick fur or plumage, and their coloration is usually

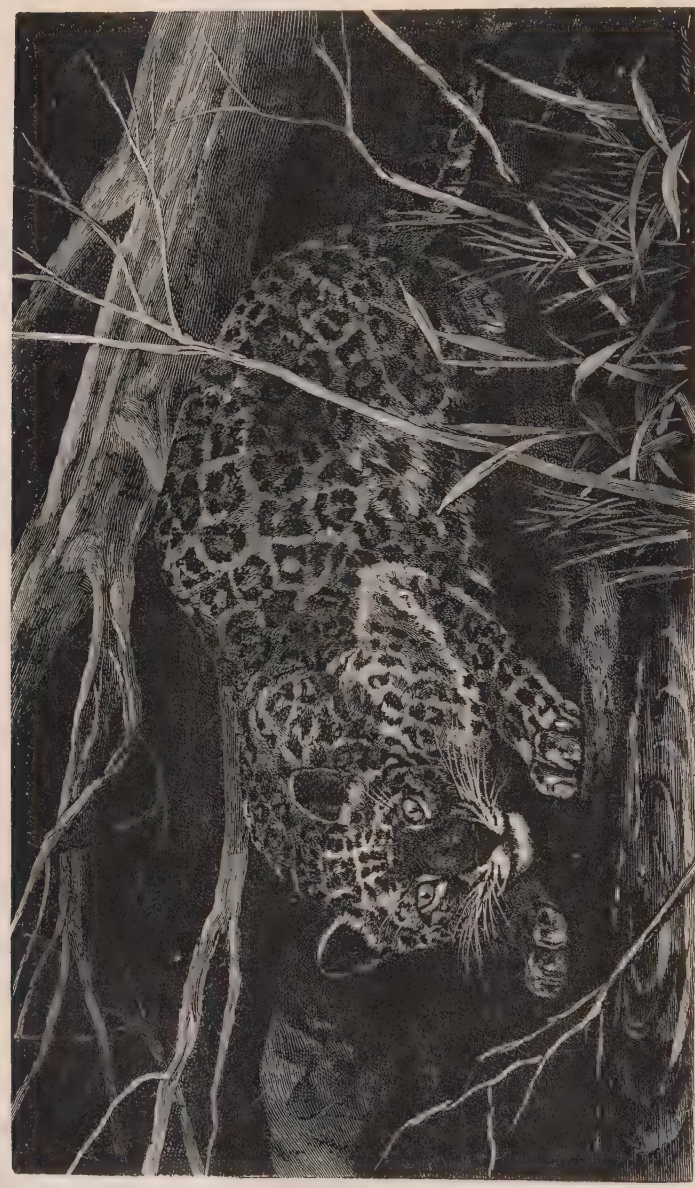

FIG. 338.—The Leopard (*Felis pardus*).—From Baker.

white, often with darker markings. There are, however, species, such as the Elk and the Musk Ox, which have not this white colouring, and in many cases, as in the Mountain or Variable Hare, the Stoat or Ermine, the Arctic Fox, the Reindeer, the Willow Grouse, and the Ptarmigan, it is assumed only in winter and in the colder part of the range of the species. Other species, such as the Snowy Owl and the Greenland Falcon, are white all the year round. A remarkable invertebrate fauna of insects and earthworms lives upon and in the snow, deriving its food, perhaps, from the minute algæ which grow there. Strangely enough, these animals are almost all black or very dark in colour. Possibly this is of

Fig. 339.—Roebuck.—From *Cassell's Natural History*.

advantage to them in enabling them to absorb the scanty warmth which the sun's rays afford in their habitat, and upon which they are dependent to make possible their metabolism, unlike the warm-blooded fauna to whom it is of importance only that they should not lose heat.

In *forests* both the conditions of life and the fauna are very different from those of the open types of country we have been discussing. To begin with, there is no lack of moisture. Such vegetation is only possible where there is a good rainfall, and in forests the air is damp and there is water, if not on the ground at least in fruits and other parts of plants or held upon the leaves. The ground is soft. The prevailing colour is green, splashed in the upper regions

of tropical forests with brilliant colours, by the flowers. Under the trees the light is subdued, but dappled in places where the sun

FIG. 340.—Wild Swine.—From Flower and Lydekker.

FIG. 341.—*Ateles ater*, one of the Spider Monkeys.—From Beddard. The Spider Monkeys are confined to South and Central America.

shines through between the leaves. An infinitely complex substratum is afforded by the branches. Forest animals fall into two

sets, those which live upon the ground and those whose home is in the trees. The ground fauna has feet with several toes, suitable for travelling over soft ground, such as are seen in elephants, rhinoceroses, tapirs, pigs, and less markedly in deer (Fig. 304, *G.*). Its colouring is sombre or dappled, as in fallow deer and various members of the cat family, and these markings are often found in the young when the adults are more evenly coloured, as in the Puma, deer, tapirs

Fig. 342.—The Dun-coloured Gibbon (*Hylobates entelloides*).—From Flower and Lydekker.

(Fig. 393), and pigs (whose young are striped). The tree fauna consists, of course, of good climbers or flyers. It has prehensile limbs or tails, or both, and tree frogs have suckers on the toes. Tree snakes are long and slender, and can thus find support in reaching from tree to tree. The various parachuting animals mentioned earlier in this chapter are arboreal; curiously they are not found in South American forests, where prehensile tails are extremely common. There is little doubt that forests have given rise to two important sets of animals—those that fly, whose wings

were developed first as parachutes to pass from bough to bough, and those that have prehensile hands, including the Lemurs, Monkeys, and eventually Man, though that is not to say that Man developed his human characteristics as an arboreal animal. For the rest, there are found in forests representatives of every group of land animals.

The forests of the world are of two main types, those of temperate climates, consisting of one or a few species of

FIG. 343.—*Leptophis liocerus*, a tree snake.—From Gadow.

trees, mainly deciduous, whose foliage is not very dense, and without brilliantly flowering epiphytes; and those of the rainy parts of the tropics, such as tropical America, West and Central Africa, and Malaysia. These are immensely luxuriant and evergreen, consist of a large number of species, and have foliage so dense that but little light reaches the ground in them. On the other hand, the tree-tops are exposed to the most brilliant sunlight, and are the seat of exuberant life. This is how Dr. Gadow describes such a forest and its inhabitants: "On its outskirts it forms an impenetrable wall of luxuriant herbage,

shrubs, and creepers. It can be entered only by slashing a path. . . . Once inside, we are in a gloomy, stuffy forest of tall, straight trees, which branch out high above us, then interlacing and forming a dense canopy of green, through which passes but little sunlight. This absence of direct light prevents the growth of underwood, and there are no green luxuriant plants, no flowers, and no grass. The ground is dark, covered with many inches of rotting leaves and twigs, all turning into a steaming mould. . . .

FIG. 344.—The Alpine Ibex (*Capra ibex*).—From Flower and Lydekker.

The observation of animal life is most disappointing to the novice. He may roam about in this gloomy forest for hours and hear little and certainly see less. Where are the two hundred different kinds of mammals, birds, reptiles, and amphibia which we know to exist in a Mexican tropical forest? Most of them inhabit the top-storey, the roof-garden, which is formed by the tree tops. If by lucky chance we obtain a bird's-eye view from a precipice or a river, we behold a different world. A dense green carpet, over-strewn with mauve, pink, yellow, or white flowers, visited by butterflies, which are pounced upon by lizards and tree frogs,

these being in turn sought after by tree snakes. Of bird life also there is plenty, often gorgeous and beautiful in colour. Vividly coloured are also many of the other creatures, frogs, snakes, lizards, and butterflies. . . . Most of the tree frogs are green, unless they are delicate studies in brown with irregular markings to suit the

Fig. 345.—The Kea (*Nestor notabilis*).—From *Nature*.

This bird frequents the rugged slopes of mountains in New Zealand. It is notorious for its acquired habit of attacking sheep and killing them by tearing open the backs in order to devour the fat around the kidneys.

moss and lichen-coloured branches upon which they rest. Some have 'flash colours,' orange, yellow, or red, on parts which are quite concealed when the creature sits still. He trusts to not being discovered, but touch him and there is a flash of yellow in the air, which vanishes in a moment, the frog also vanishing. He has

dazzled his pursuer by this sudden and unexpected display of colour, has then caught hold of a leaf with some of his adhesive finger discs, vaulted on to it, and there sits demurely undistinguishable from the foliage. Many tree snakes are green, and so are many parrots, motmots, and other typical tropical forest birds. Other parrots, pigeons, toucans are loudly coloured, but these very colours mingle with the bright surroundings to a marvellous extent. Tropical light can be so fierce and resplendent that a whole flock of bright parrots in a tree will simply vanish. If we now descend in our survey below the tree roof, there are, of course,

FIG. 346.—The Alpine Marmot (*Arctomys marmotta*).—From Flower and Lydekker, after Brehm.

many creatures which live habitually upon the branches or stems of the trees. These have sombre tints, brown, speckled, or barred. Lastly, those which live on the ground floor, or in the basement, are mostly dark." Not all tropical forests, however, are of the rain-forest type. Thus in Uganda, besides the rain-forests, there are "savannah" forests, less dense than the rain-forests, and composed of smaller trees with spreading crowns and a luxurious growth of grass underneath, and bush forests of small, bushy trees and shrubs.

Mountains have not one but many faunas. A high mountain is a microcosm. As it ascends from the plain it bears zones whose

climates are such as would be passed through in travelling from it to the nearer of the poles. In the tropics it will have first a tropical zone, forested or arid as the case may be ; then others that are subtropical ; temperate, with deciduous trees ; cold, with grass and flowers passing into mosses and lichens ; and, finally, snow-covered throughout the year. In each of these lives a fauna that is similar to, though not identical with, that of the corresponding belt of the

FIG. 347.—The Condor (*Sarcorhamphus gryphus*).—
From Evans.

earth's surface. The population of these zones reaches them in various ways, usually in more than one. It may immigrate from below, gradually changing as it goes ; or travel along a range of fellow-mountains from a cooler climate nearer the pole ; or be a relic of a fauna that once covered the adjoining plains and has since been killed off there by some change in climate, as the Mountain Hare of Northern Europe, found also in the Alps, Pyrenees, and Caucasus, is by some authorities believed to be a relic of the ice

age of the continent; finally, it may wander from mountain to mountain, or from a colder region, as birds can do. Well-known examples of mountain animals are the Goats and Ibexes (*Capra*) and Sheep (*Ovis*) found on mountains throughout Asia, Europe,

FIG. 348.—The Musk Deer (*Moschus moschiferus*).—From Flower and Lydekker.

and North Africa, the allied Chamois of Europe and Rocky Mountain Goat of North America, the Yaks and Musk Deer of the Himalayas, the Mountain Hare and Alpine Marmot, the Condor of South America, the Lammergeier and Golden Eagle of Europe, and the New Zealand Mountain Parrot or Kea.

CHAPTER XII

THE EVOLUTION OF FAUNAS

On the mountain peaks we brought to an end our survey of the faunas of the world. Throughout it we have found tokens of two processes—evolution and migration—the acquirement of new features of organization and habit, by which animals have attained more and more mastery over their surroundings, and the invasion by them of one province after another, as their new powers enable them to cope with fresh conditions. Sometimes, of course, the establishment of a fauna adapted to new surroundings has taken place without an actual migration. From the first, animals must have been brought under different conditions in two ways—by an alteration of their native environment, as when a lake becomes a swamp, and a swamp dry ground, and by wandering or being carried into new and different localities. But either of these events amounts to the same thing for the animals. Forwards and backwards they have gone, between sea and river, marsh and plain and forest, pressing ever into new conditions, and even time after time returning into an earlier habitat, bearing the stamp of a double or triple reversal of the conditions of their life. We must not here speculate upon a question which we have already (p. 8) dismissed, as to how far evolution has come about by spontaneous variation in that restless protoplasm which is the essential part of living beings, and how far external conditions acting upon this substance, as plastic as it is energetic, may have set up habits of action and growth by which animals were changed ; but it is of the essence of our task to observe that the differences which evolution has established go hand in hand with differences in environment, and we may reflect that, at least, external conditions, by determining whether any change in a species of organism should be successful or not, must have played a great part in bringing about this correspondence between the living creature and its surroundings.

Piecing together what we have noted, we recall that life probably began—how it was not our business to inquire—in the shallow waters beyond tide marks, at a time when the lately formed ocean was less salt, and of different percentage composition from that

which we know. It is, perhaps, most likely that the first organisms, whether they rested on the bottom or floated, arose in warm, quiet waters which were relatively well supplied with phosphates and other salts by the neighbouring land. In these conditions, it may be supposed, protozoa came into being, and started the long history of animal evolution. On the whole, as their evolution proceeded, animals must have become more and more fitted to travel. Organs of locomotion and sense, developed first, perhaps, for use within a limited area, made them better voyagers, but it may be that the most important of their acquisitions in this respect were the various forms of cuticle and shell by which

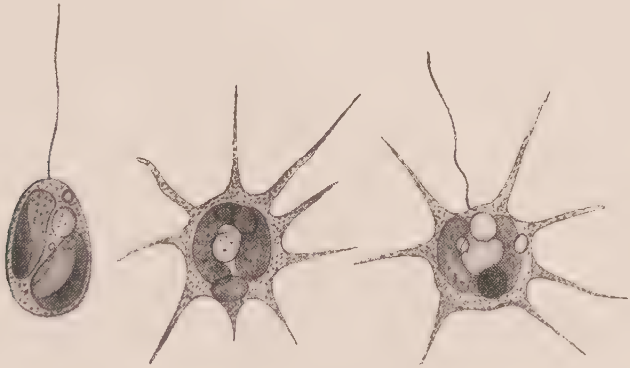

Fig. 349.—*Chrysamœba*, a primitive protozoon, which combines features of plants and animals, and of flagellates and rhizopods.—From Doflein.

A., The flagellate condition; *B.*, the amœboid condition; *C.*, a transitional stage. The body contains chromoplasts, like those of plants.

they were in some measure protected against unwonted conditions of salinity, temperature, and moisture.

However the first living beings may have been nourished—and this is an exceedingly obscure problem, for which a solution must probably be sought among simpler types of photosynthesis than that which a special apparatus makes possible in green plants [1]—protozoa must early have become predatory upon the vegetable organisms which were differentiating from the same stock, and upon one another. There is reason to believe that

[1] The faculty of photosynthesis, which was probably possessed by the earliest organisms and has been developed and specialized by green plants, may not have been entirely lost by animal organisms. It is quite possible that some of Pütter's results (p. 193) are thus to be explained. An instance of photochemical action in the human body is mentioned on p. 33.

these primitive animals were flagellate. Some such became sessile, and gathered food from the water about them; and

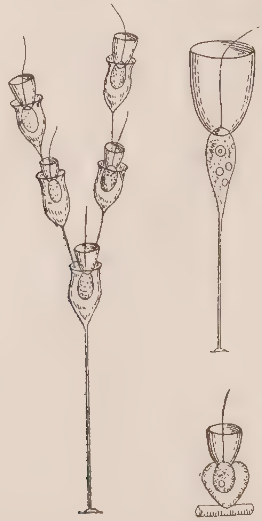

Fig. 350.—Choanoflagellata or collared flagellates. Sessile, flagellate protozoa, solitary or colonial, of the same type as the cells which line the flagellated cavities in sponges.

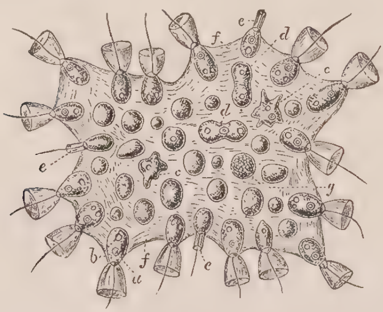

Fig. 351.—*Proterospongia*, a colonial choanoflagellate which by the types of individuals which compose the colony, and by the jelly which unites them, resembles the sponges.

a., Nucleus; *b.*, contractile vacuole of collared cell; *c.*, amœboid individual in the jelly; *d.*, division of such a unit; *e.*, flagellate cells with collars contracted; *f.*, covering membrane; *g.*, individual dividing to form spores (? gametes).

A rearrangement by which the colony formed a hollow vase lined by the collared cells, with a flattening of the cells on the outside, would produce something very like a sponge.

from certain of these which had become also colonial the Sponges probably arose, by rearrangement of the individuals to form a

hollow colony so that their united action set up more powerful food-currents. Others remained free from the substratum and travelled

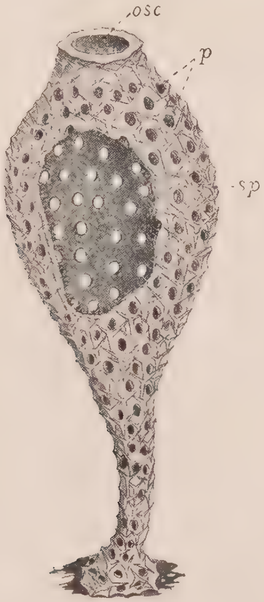

FIG. 352.—The Olynthus, a simple type of sponge.

osc., Principal opening or osculum of the sponge, through which a current sets outwards; *p.*, pores, through which the current sets inwards; *sp.*, spicules which strengthen the wall.

Note on the cut edge the flagella of the collared flagellate cells which line the cavity and set up the current.

in search of their nutriment; and it must have been from among these that, by a process which has been variously conceived as the

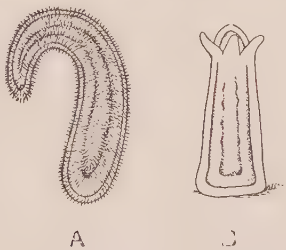

FIG. 353.—*A.*, Planula larva; *B.*, the young polyp into which the planula grows after settling.

formation of motile colonies in which differentiation of the individuals took place, and as a multiplication of nuclei to take charge of

the differentiated tissues which made possible a more complex life, there arose the Metazoa—probably at first as something like the "planula" larva of a zoophyte. As this became more bulky it developed the first of those spaces in which water subserves internal yet extraprotoplasmic functions in the bodies of animals, namely, the enteron, as yet both a digestive and a circulatory cavity. At this stage, again, certain animals became sessile, acquiring the radial symmetry which is characteristic of that mode of life, and giving rise to the typical Cœlenterates (*Cnidaria*). Others con-

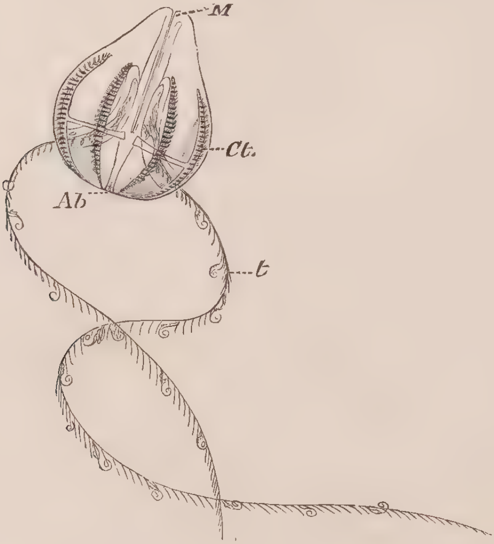

Fig. 354.—*Hormiophora plumosa*, a ctenophore.—From Hickson, after Chun.

Ab., Aboral pole; *Ct.*, rib of swimming plates of fused cilia; *M.*, mouth; *t.*, tentacle.

tinued to wander, still, probably, swimming by their covering of cilia, the most primitive of swimming organs. From these arose, on the one hand, the Ctenophora, which joined the medusæ that the sessile zoophytes had begun to set free, and preyed upon the plankton whose development, from plants, protozoa, and the larvæ of other organisms, now made possible a pelagic fauna. On the other hand, a more benthonic mode of life required different and denser tissues and a well-developed mesenchyme, and thus, perhaps, gave rise to the earliest flatworms. Here began four important developments—that of an excretory system to serve the mass of internal tissues; that of a definite central nervous system, as cords and

masses of nervous tissue, condensed in the nerve network under the surface of the body that had served simpler metazoa; of that a definite "bilateral" symmetry, with back and belly, right and left sides, which is essential to an animal that moves about swiftly; and that of a head, a foremost region which bears the principal sense

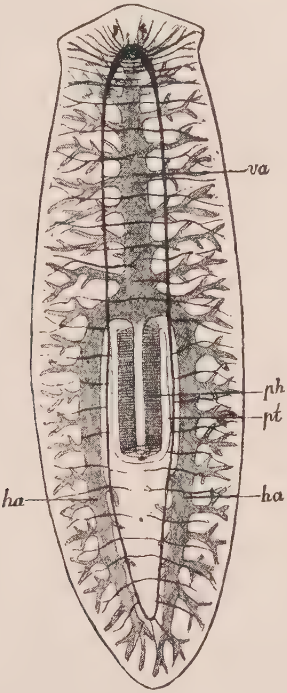

FIG. 355.—A diagram of the anatomy of a (triclad) flatworm.—From Lang.

The animal is bilaterally symmetrical, with a head which is richly supplied with nerves running to various sense organs and contains a brain. From the brain nerves run along the body. There is a (branched) gut (*va. ha.*) with a muscular pharynx—though this does not open on the head—but no anus. Between the epidermis and the gut lies a spongy mass of mesenchyme.

organs, the brain, and usually the mouth, and, coming first into relation with new surroundings, is a necessary specialization for a bilateral animal that leads an active and complex life. Soon the increasing complexity of the body demanded further internal spaces, for circulation and for the accommodation of the generative cells. To meet these needs arose the blood-vascular and the

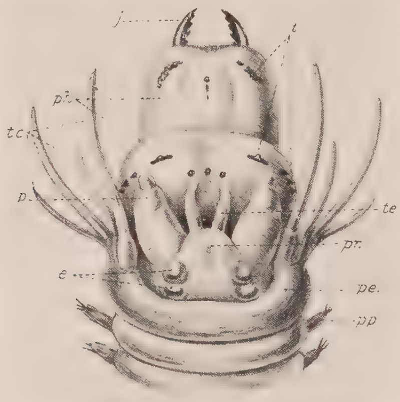

FIG. 356.—The head of *Nereis*, with the pharynx protuded.
e., Eyes ; *j.*, jaw ; *p.*, palp ; *pe.*, peristomium (first two segments, fused) ; *ph.*, pharynx ; *pp.*, first ordinary parapodium ; *pr.*, prostomium ; *tt.*, accessory teeth ; *tc.*, tentacular cirri ; *te.*, tentacle.

Note that the head is formed from several of the anterior segments, and that it bears several sense organs of different kinds, and the mouth with structures accessory thereto.

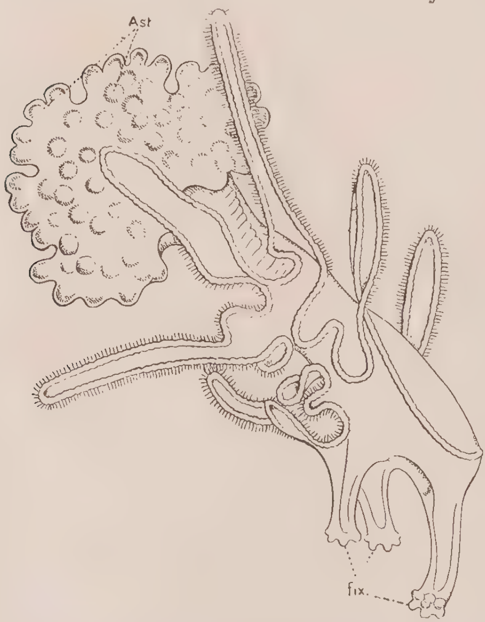

FIG. 357.—The *Brachiolaria* larva of a starfish fixing itself.—From MacBride, after Johannes Müller.
Ast., Rudiment of the future body of the starfish ; *fix.*, fixing processes of the larva.

cœlomic or true body-cavity systems; and now all the essential parts of the body of the higher animals were in being. At this stage yet another contingent joined the sessile animals. Among them were some that, supporting their bodies by an internal calcareous skeleton, became the earliest echinoderms, which were fixed, like the Sea Lilies and the larvæ of many starfishes. Later, certain of these broke loose again and gave rise to starfishes and thus to other classes of the Echinodermata, which retain a radial symmetry that betrays their sessile ancestry, though the Ophiuroidea by the high development of their arms, and the Sea-Urchins and Holo-

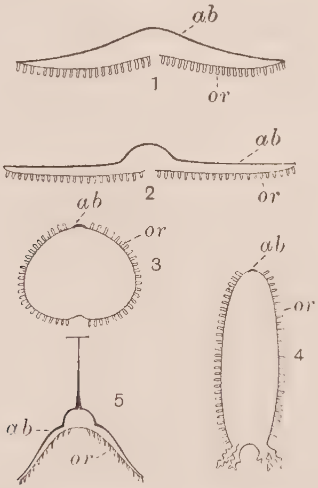

FIG. 358.—Diagrams to compare the morphology of the extant classes of echinoderms. The body is placed in the same morphological position in each case, so that the crinoid (5) is inverted, and the holothurian (4) at right angles to its natural position.

1, Starfish; 2, brittle star (ophiuroid); 3, sea urchin; 4, holothurian; 5, sea lily (crinoid). *ab.*, Aboral or abambulacral surface; *or.*, oral or ambulacral surface.

thuroidea by change of shape and the shrinking of the abambulacral surface, differ widely from the Starfishes. The animals that remained free developed in two directions. Some of them, probably related to those from which echinoderms arose, formed their central nervous system along the back, turned it in to become a tube, and presently sheltered it, as the brain and spinal cord, within part of an internal skeleton which came to support their bodies and later became calcified. In these back-boned animals there were developed a powerful postanal swimming region—the tail—and a set of gill-clefts leading through the sides of the throat to the outer water

and subserving a characteristic mode of breathing. Thus arose the Protochordata, and eventually the Fishes. Others of the cœlomate animals had a double nerve cord along the belly and did not possess an internal skeleton, a tail, or gill-clefts. From these there arose, on the one hand, the Mollusca, which, remaining unsegmented and keeping a soft skin, secreted a calcareous shell, and

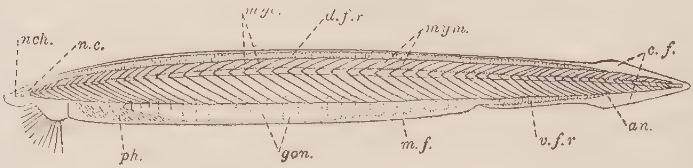

FIG. 359.—The Lancelet (*Amphioxus*), illustrating by certain of its features the primitive anatomy of the Vertebrata.

an., Anus; *c.f.*, caudal fin; *d.f.r.*, rays of the dorsal fin; *gon.*, generative organs; *m.f.*, metapleural fold; *myc.*, myocommata or septa of connective tissue between *mym.*, the myomeres; *n.c.*, nerve cord; *nch.*, notochord; *ph.*, pharyngeal wall with gill clefts; *v.f.r.*, rays of the ventral fin.

diverged into three principal groups, those of the gastropod or whelk type, the bivalve or mussel type, and the cephalopod or cuttlefish type. On the other hand, they gave rise to the Annelid worms, which developed a tough, chitinous cuticle and became highly seg-

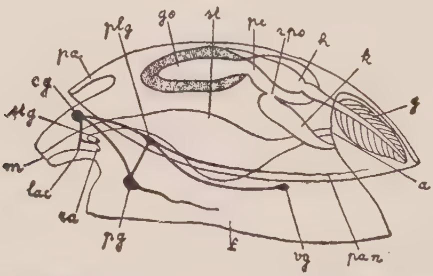

FIG. 360.—A diagram of the anatomy of the hypothetical ancestor of the Mollusca.—From Lankester.

a., Anus; *c.g.*, cerebral ganglion; *f.*, foot; *g.*, gill, in the mantle cavity; *g.o.*, generative organ; *h.*, heart; *k.*, kidney; *la.c.*, labial commissure of nervous system; *m.*, mouth; *pa.*, mantle; *pa.n.*, mantle nerve; *p.e.*, pericardium; *p.g.*, pedal ganglion; *pl.g.*, pleural ganglion; *ra.*, radula; *r.p.o.*, renopericardial opening; *st.*, stomach; *st.g.*, stomatogastric ganglion; *v.g.*, visceral ganglion.

mented. The Annelids in turn gave rise to the Arthropoda, which, increasing the thickness of the annelid cuticle, became better armoured, and could attach their muscles to better advantage, but had to joint the cuticle at intervals in order to move. They elaborated the paddle-like parapodia of polychæte annelids into strong limbs, adapted to various functions, notably to feeding, for

which worms do not use their parapodia. The groups of arthropods which arose in the sea were the Crustacea, of which the Trilobites were probably the earliest members, and the Merostomata, including the King Crab (*Limulus*) and the now extinct Eurypterida. To

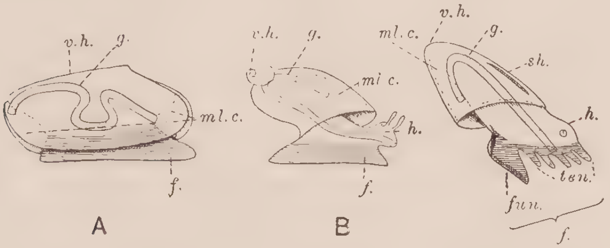

FIG. 361.—Diagrams of a bivalve mollusc (*A.*), a gastropod (*B.*), and a cuttlefish (*C.*).—Partly after Lankester.

f., Foot; *fun.*, funnel through which water is squirted by the cuttlefish in swimming; *g.*, gut; *h.*, head; *ml.c.*, mantle cavity; *sh.*, internal shell found in some cuttlefish (the "cuttle bone"); *ten.*, tentacles of the cuttlefish; *v.h.*, apex of visceral hump.

the natural inquiry as to what may have been the features of the primitive water environment to which all these developments corresponded, there is no very clear answer. But it would seem likely

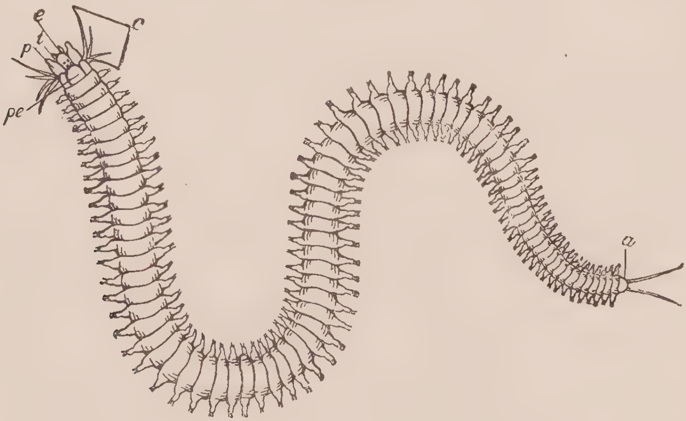

FIG. 362.—*Nereis cultrifer*, illustrating the structure of the polychæte worms.

a., Anus, with two long cirri; *c.*, tentacular cirri; *e.*, eyes; *p.*, palp; *pe.*, peristomium; *t.*, tentacles.

that at first animals were affected by the opportunity of availing themselves of the plant food around them, and that subsequently they entered upon that path of antagonism between predator and prey which needs ever a more and more complex equipment of the

antagonists. Thus the earlier steps in evolution, by which, in the dimmest past, all the principal groups of animals came into being, may have been in correspondence more with the internecine affairs of the realm of organisms than with its relations with inorganic surroundings which were probably equable and favourable ; though the suggestion has been made that the organization of the primitive chordates, with tailed and powerfully muscled, fish-like bodies, arose in animals that had to hold their own against currents. The

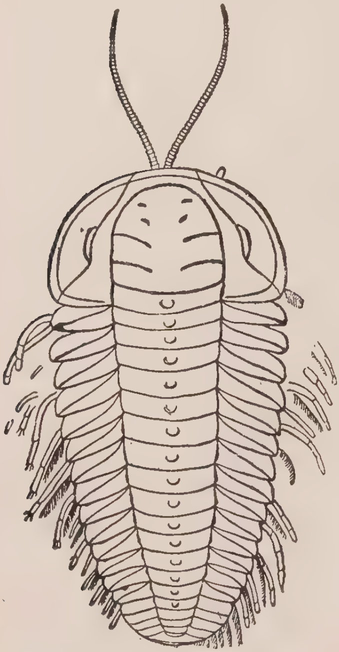

FIG. 363.—*Triarthrus becki*, a trilobite. —From Sedgwick, after Beecher.

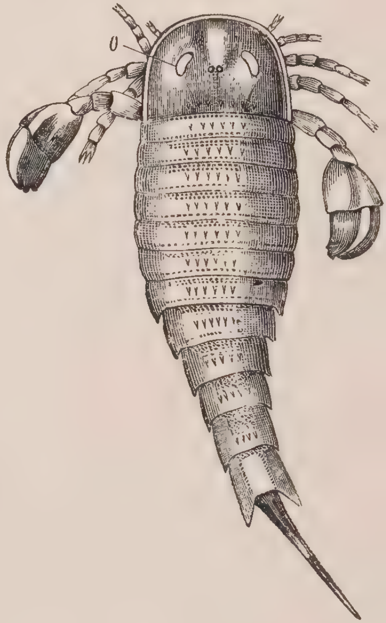

FIG. 364.—*Eurypterus remipes*.—From Sedgwick, after Nieszkowski.

further suggestion that this indicates a river origin for such creatures is less convincing.

By now, however, there had begun those migrations into fresh waters and on to land which brought animals into severer inorganic conditions, and were accompanied by important steps in evolution that established the peculiar faunas of those environments. The movement into fresh waters was perhaps in the main a direct one, and may at first have been easier than it has since become, because there was then less difference in salinity between the

waters of the rivers and those of the sea; but there may well have been a relict element in earlier as there has been in later times. The migration was no doubt chiefly performed by members of the benthos and nekton, and not by the plankton, which is ill adapted to travel upstream. The freshwater plankton is a new development from the freshwater benthos, to which its members are more nearly related than they are to the marine plankton. Naturally enough, the colonizing of fresh waters produced fewer new types of animal than did that of the land, where the conditions of life differ so much more from those of the sea, and are more varied, and the habitat is not so liable to be entirely destroyed at what are, geologically speaking, short intervals of time. Nevertheless this migration was marked by the appearance of significant features in the animals that accomplished it, and gave rise to several new and very important groups. We have already seen (pp. 247, 252) what common features have been acquired by freshwater animals,

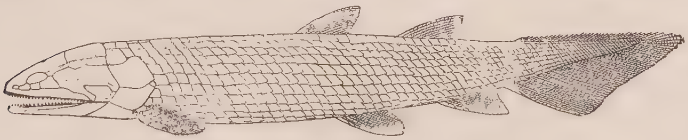

FIG. 365.—*Osteolepis*, an early (Devonian) ganoid fish.—From von Zittel.

what groups of marine animals have been able to establish themselves in fresh waters, and which are now only, or principally, to be found there. Of these latter, the Branchiopoda and Rotifera are perhaps marine in origin, but are able to exist in larger numbers in their new habitat than in the conditions of the modern ocean. The Ganoid Fishes, Amphibia, Dipnoi, Oligochæta, and Heliozoa, on the other hand, probably came into being in fresh waters The Ganoids represent the first stage in the evolution, from the primitive fishes—which, like modern sharks, were cartilaginous and had no "swim-bladder"—of the bony vertebrates, provided with swim-bladders or lungs, which constitute the backboned fauna of fresh waters and the land, and have sent back numerous of their members to the sea. The origin of bones in these creatures is mysterious. Bone already existed in the scales of cartilaginous fishes, and it probably spread thence to the internal skeleton. Possibly this was part of a perfecting of the swimming mechanism which was necessitated by the strong and constant currents of fresh waters: certainly without it the vertebrate body could not eventually have been supported in air. Swim-bladders seem to have arisen as an

apparatus for air-breathing, such as we have seen to appear again and again in the inhabitants of fresh and brackish waters. The

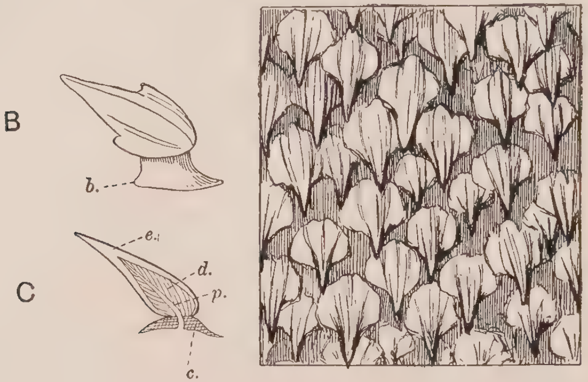

FIG. 366.—Placoid scales of a cartilaginous fish (the Dogfish).

A., A portion of the skin of the fish seen under a hand lens ; *B.*, a single scale removed from the skin ; *C.*, the same in section (diagrammatic).

b., Base of the scale ; *c.*, the same in section ; *d.*, dentine ; *e.*, enamel ; *p.*, pulp cavity.

great advantages which air possesses for respiration would probably by themselves account for its being used when that became possible,

FIG. 367.—A section of dry bone magnified. The dark spaces show where the living part of the tissue was lodged.

lac., Spaces known as "lacunæ." In these lay the cells into which the protoplasm was divided. *g.s.*, ground-substance. This is traversed by numerous "canaliculi" in which processes of protoplasm united the cells into a meshwork. *H.c.*, "Haversian canals" in which minute blood vessels lay. The lacunæ are so arranged as to divide the ground-substance into concentric layers or "lamellæ" around the Haversian canals.

as it does in such waters. It may be, indeed, that, with the exception of a few gastropod molluscs, all air-breathing animals

become such during a sojourn in fresh or brackish waters. From the Ganoids were derived, on the one hand, the typical bony fishes (*Teleostei*), and, on the other, the Dipnoi and Amphibia. The Teleostei appear to have arisen from ganoids which had descended to the sea and there lost the habit of breathing air and often even the connection between the mouth and the swim-bladder, so that the latter became a purely hydrostatic apparatus.[1] Later, certain of these returned to fresh waters and there, as we have seen, some reacquired a partial air-breathing habit. Finally, in the bewildering

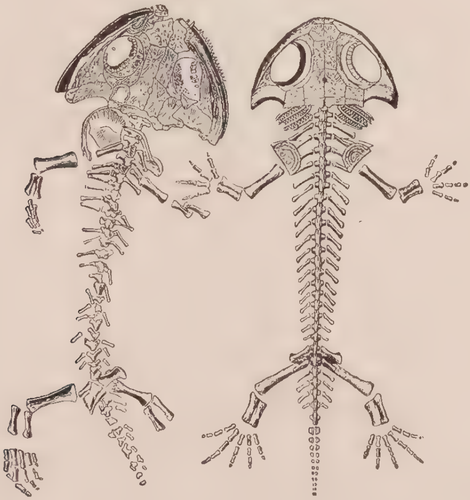

FIG. 368.—*Branchiosaurus*, one of the early group of amphibians known as Stegocephali.—From von Zittel.
A., Larva, showing gills; *B.*, adult.

interchange between the faunas, some, such as the Salmon, once more entered the sea. The Dipnoi bring nearer to its culmination the ganoid tendency to breathe air, but, owing perhaps to something antiquated in their constitution, they are now a dwindling group. The Amphibia have taken the final step of developing veritable lungs, and with them landgoing, pentadactyle limbs. They are essentially an amphibious group, and perhaps their more aquatic members are rather relapsed than laggards in evolution. In spite of their resemblance in certain respects to the Dipnoi, there are various facts—notably the peculiar jaws and form of limb

[1] It is probably of more importance as a sense organ for determining depth by pressure than as a buoyancy apparatus.

and cycloid scales found in the latter group—which make it unlikely that the Amphibia were developed from them. More probably they took origin from fishes related to the Crossopterygian Ganoids. The Heliozoa are an imitation of a marine pelagic group, the Radiolaria, whose naked and delicate protoplasm has not adapted itself to fresh water. Why the Oligochæta should in that environment

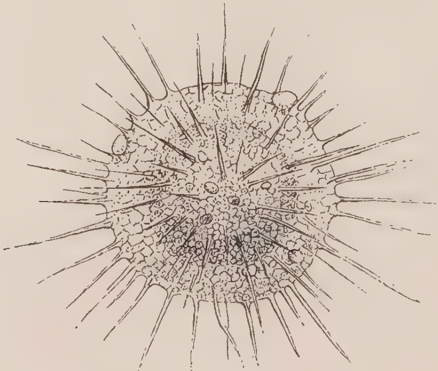

FIG. 369.—*Actinosphærium eichorni* (Heliozoa).

replace polychæte worms, is not clear. Their peculiar features—the absence of limbs (parapodia) and the complicated hermaphrodite generative organs—are at least not obviously adaptations to it.

Whether there were an actual landward migration, or a gradual raising of the bottom of shallow waters into the air, so that, while

FIG. 370.—A restoration of the Permian reptile *Limnoscelis paludis*.—From Lull.

some of its animals died out, others became first amphibious and then terrestrial, is not certain. Probably both things happened. Clearly a part of the fauna of the land reached it through fresh waters. The Amphibia were certainly added to it from this source; and from them it evolved, through the Reptiles, all the other groups of the higher Vertebrata, by a gradual perfection of the limbs, the breathing apparatus, and the covering of the body, and the establishment of a mechanism for maintaining

an even internal temperature in face of the great variability of the external temperature to which they were subjected in a terrestrial life. It seems likely that reptiles came into being (towards the end of the Palæozoic period) in conditions that were arid, and therefore unsuited to the amphibian organization and mode of life; and that mammals arose from reptiles (at the beginning of the Mesozoic age) in cold surroundings that gave an advantage to the warm-

FIG. 371.—*Archæopteryx macrura*, restored, about ⅛ natural size.—After Flower.

Archæopteryx, which is known only by two fossils from the Upper Jurassic, is a remarkable link between birds and reptiles, having teeth, free fingers on the hand, and a long, jointed tail.

blooded physiology; while birds took origin, also in Mesozoic times, from reptiles that had adopted an arboreal life. The Earthworms doubtless also arose from freshwater ancestors. On the other hand, the Arachnida, which must have had marine forbears related to the Merostomata, and the Insects, which probably arose from the higher Crustacea, *may* have come from the sea; though it is perhaps more probable that, like most air-breathing groups of animals, they arose in fresh waters. The various

"snails" had probably a mixed origin. Of the operculate (prosobranchiate) forms, some, such as *Cyclostoma*, undoubtedly arose from marine periwinkles (*Littorinidæ*); others, such as *Helicina*, from operculate freshwater snails. The Pulmonata Stylommatophora (ordinary snails) arose from marine opisthobranchs, but they may have done so through freshwater snails

FIG. 372.—*Stenodictya lobata*, an early (Palæozoic) insect.—From Lull, after Handlirsch.

allied to the Pond Snail (*Limnæa*). The land amphipod and isopod crustaceans appear also to have come from the sea. All these invertebrates have suffered, in their degrees, a land change, which consisted primarily in the adaptation to breathing air.

Once established, the freshwater and land faunas began to contribute members to one another and to that of the sea. We

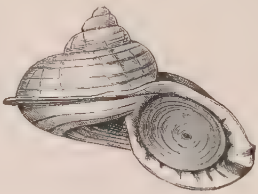

FIG. 373.—*Cyclostoma campanulatum*, an operculate land "snail."

have just seen what were the principal groups of migrants from fresh water to land; and on p. 253 there is a brief list of those that migrated in the reverse direction. These returned immigrants have, as has been shown, undergone considerable modification to readapt them to their aquatic habitat. If we except the members of the brackish water fauna, and the problematical case of the bony fishes, the tale of freshwater animals established in

the sea is rather short. It consists of a few heliozoans, oligochæte worms (*Clitellio*, etc.), molluscs (*Neritina*, etc.), and fishes. Either directly or indirectly through fresh waters, the sea has received a rather larger contingent from the land. Some insects, especially larvæ found near the shore but quite aquatic; stray members of other arthropod groups; snails; many extinct reptiles, and even a few labyrinthodont amphibia (*Onchorhynchus*, etc.); and the Sea Cows (*Sirenia*), appear to have migrated direct from land to sea. Other insects, such as *Halobates*, mites, and the Whales, are examples of those that took the route through fresh water. Cooke quotes an interesting series which shows how animals have changed

FIG. 374.—The Dugong (*Halicore*).

their habitats to and from sea, fresh water, and land. *Nerita* is a marine operculate gastropod, of which some species occur in brackish water. *Neritina*, closely related to it, is a freshwater genus with amphibious species. *Helicina*, of the same family, is a land snail. *Smaragdia* has returned to the sea. We have already seen how in the amphibious fauna members of all the others meet. Here also exchanges take place. The Crocodiles, which are now members of the freshwater amphibious fauna, started on the shores of the sea. The Sea Otter comes of a freshwater amphibious stock. There are even cases, as some among the Otters, where amphibious animals have returned to a purely terrestrial habitat.

In the opposite direction, though later, when the surface waters

had come to contain enough food to make provision for the depths, the colonization of the deep sea from shallow waters appears to have taken place. We have seen what are the modifications which the members of its fauna have undergone in the process. Probably the first immigrants arrived while the waters were still warm, and later sets came with the cold water from the poles when the cooling had set in. Those of the first arrivals which survived the change in temperature are responsible for the archaic element in the fauna. The later arrivals gave it its polar character, and it is possible that some of them, making the journey from one pole to the other, aided in bringing about that resemblance of the polar

FIG. 375.—The Sea Otter (*Enhydris lutris*).—From Flower and Lydekker, after Wolf.

faunas which is known as "bipolarity," though probably this is largely due to similarity of conditions at the two poles.

Meanwhile, in all the various types and subtypes of locality, by land and sea and in fresh waters, there were being evolved the types of fauna which we have seen to characterize them. But here we are faced with a problem. For we find, especially on land, that localities with practically the same conditions of life are occupied by faunas which, though they show similar adaptations to them, differ very greatly in other respects. Why is it, for instance, that in the tropical forests of South America, so much alike in their general conditions of life to those of Africa, the fauna belongs to such different families? Why should the broad-nosed

Marmosets and Spider Monkeys here represent the narrow-nosed Monkeys of the Old World? Why do the tree frogs belong to the family Hylidæ, and not, as those of Africa do, to the Ranidæ[1]

A

B

FIG. 376.—Heads of an Old World Monkey (*A.*) and a New World Monkey (*B.*).—After Duncan.

to which our own frogs belong? Why is there no elephant, rhinoceros, hippopotamus, civet cat, or insectivore? Why is it that

[1] A peculiar genus (*Dendrobates*) of ranid tree-frogs exists in the north of South America.

here alone there live sloths, armadillos, true ant-eaters (*Myrmecophagidæ*), toucans, sugar-birds, motmots, heliconid butterflies, and a vast number of other animals; that tapirs are found only here and in similar districts of Malaysia; and so forth? Why, again, have the various types of habitat in Australia, plains, forests, mountains, and deserts alike, a mammalian fauna which, while it is adapted to its several habitats quite as well and in the same general ways as those of the rest of the world, consists solely of the Pouched Mammals or Marsupialia and of the little group of the primitive, egg-laying Monotremata, both of which are almost absent elsewhere? We have seen that likeness between the members must not be looked for in a geographical fauna, because of the various conditions of life—mountains, forests, fresh waters,

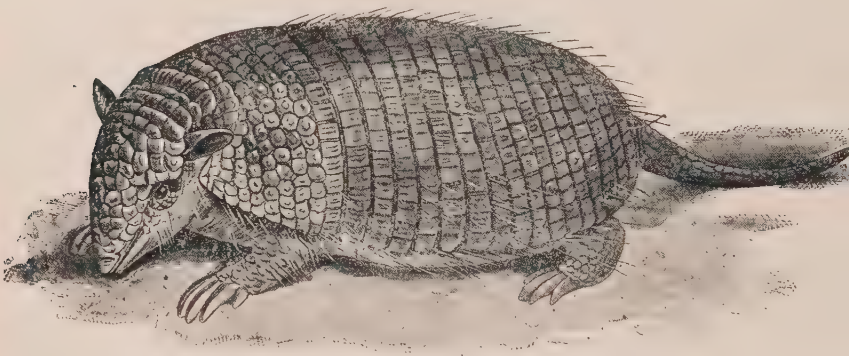

FIG. 377.—The Peludo Armadillo (*Dasypus sexcinctus*).—After Vogt and Specht.

etc.—which it contains. But why is it that geographical divisions of an œcological fauna differ? The answer is to be found in the history of the Earth itself. While evolution has been proceeding the face of the globe has been changing, and that not uniformly. Thus any type of conditions, as, for instance, that of tropical forests, has arisen in unconnected localities whose previous history has been different, so that the animals which were the raw material for the evolution of the faunas, being different, produced different results, and none of the localities has been able to contribute by emigration to the fauna of the other. When the present faunas of Africa and South America began to be developed, the two continents were already separate and doubtless were receiving from the lands adjoining them contingents of quite different animals, while they were not able to exchange those which evolved in them.

Had their tropical forests been connected, probably the Hylidæ would have spread over both of them, and the Ranid Tree-Frogs would either not have been developed or would have reached South America. Similarly it is probable that other animals peculiar to

Fig. 378.—The Ariel Toucan (*Rhamphastus ariel*).

South America would have established themselves in Africa, and *vice versa*. Again, if Australia had not been separated from the land of the northern hemisphere before the higher mammals took origin there, it might either have received, for instance, ungulates and carnivores, or have evolved something less unlike them than

the marsupials that now play their parts in it. It is indeed remarkable that Nature has produced in similar conditions faunas with

FIG. 379.—The Duckmole (*Ornithorhynchus anatinus*).—From Flower and Lydekker, after Gould.

FIG. 380.—The Tasmanian Wolf (*Thylacinus cynocephalus*).—From Flower and Lydekker.

features that, superficially, are so much alike. Some ranid tree-frogs cannot be distinguished from members of the Hylidæ

without dissection, and the Tasmanian "Wolf" is a remarkable imitation of a dog.

These facts suggest that it might be possible to describe the

FIG. 381.—The Hoazin (*Opisthocomus cristatus*).

Among the many peculiarities of this bird is the fact that its young have claws on the first two digits of the wing, and by their means clamber about the branches of the waterside thickets which their parents inhabit.

distribution of the animal kingdom by mapping out the world into regions, to each of which the majority of the families of animals which inhabit it should be confined, as, for instance, that South America might form such a region, containing the animals named

above, and the Llamas, Oil Birds, Hoazin, Tinamous, Rheas, etc., and lacking animals that we have mentioned, and various others.[1] This attempt has been made, and many sets of "Zoological Regions" have been drawn up in the endeavour to find a correspondence between the distribution of animals and present geographical boundaries. The most famous of these divides the world into six regions —the *Palæarctic*, comprising Europe, Africa north of the Sahara, and Asia north of the Himalayas; the *Nearctic*, comprising North

FIG. 382.—Tinamous (*Tinamotis*).
Primitive and aberrant ground-living birds of South America.

America; the *Neotropical*, comprising South and Central America and the West Indies; the *Ethiopian*, comprising Africa south of the Sahara and Madagascar; the *Oriental*, comprising Southern Asia and the East Indies down to a line, known as "Wallace's Line," which passes between the two little islands of Bali and Lombok and is marked by a curiously sharp change in certain

[1] *Any* continuous portion of the earth's surface has, in a sense, a *geographical* unity: its fauna is a geographical fauna. If it be large enough, it will contain, under the various conditions which it presents, samples of various œcological faunas: each of these has an *œcological* unity. What has been aimed at in defining "zoological regions" is that in each local œcological fauna the members of each group of animals should be a *morphological* unit.

elements of the fauna; and the *Australian*, comprising the East Indies south of Wallace's Line, Australia, and New Zealand. By many authors these regions are brigaded into three—*Arctogœa* for

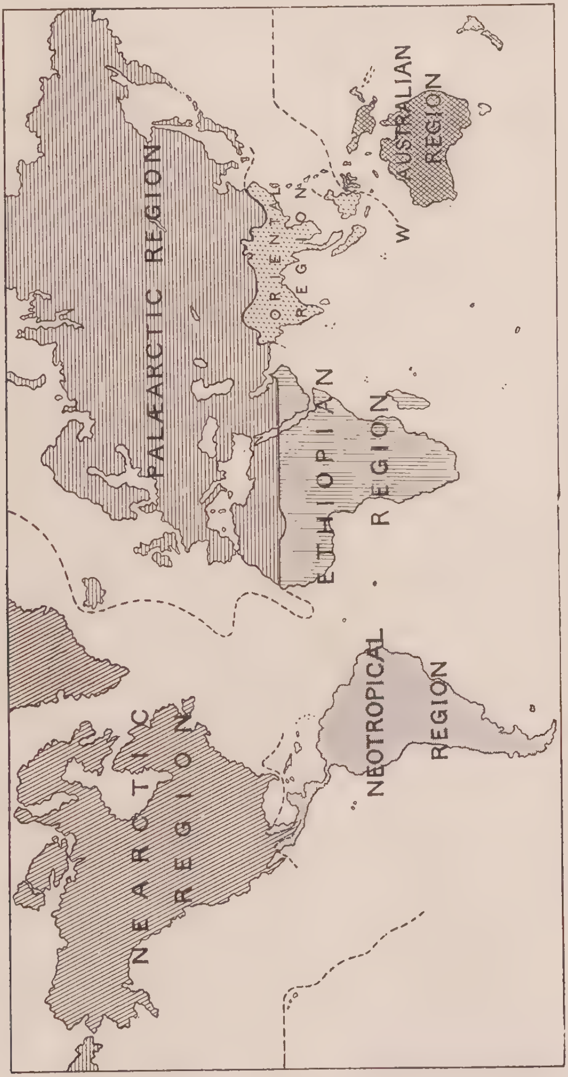

FIG. 383.—A Map of the Zoological Regions of the World, as defined by Wallace.

W., Wallace's line.

the Palæarctic, Nearctic, and Oriental regions; *Neogœa* for the Neotropical, and *Notogœa* for the Australian—and some would unite the Nearctic and Palæarctic into a *Holarctic* region, of which

they are primary subregions. We have already mentioned some instances of the facts upon which this system of regions is based, and in particular those which characterize the neotropical Region or Neogæa. The Australian Region (Notogæa) stands apart from the rest, not only by the peculiarities of its mammalian fauna, but also by the exclusive possession of various birds, such as the Birds of Paradise, Cockatoos, Emus, and Cassowaries, and by the absence of the Pheasants, Woodpeckers, Finches, etc. Arctogæa has most of the Ungulata and Insectivora, the Katarrhine (narrow-nosed) Monkeys, many families of birds, and the Ganoid Fishes. Within it, the Ethiopian Region is characterized by possessing the Gorilla and Chimpanzee, most of the Lemurs, various remarkable insectivores, such as the Golden Moles (*Chrysochloridæ*), the River Shrew (*Potamogale*), the African Elephant, the Hippopotamus, several species of Rhinoceros, the Zebras, the Giraffes and Okapi, many species of the Antelopes, the Aardvark (*Orycteropus*), the Secretary Bird and many other birds, the freshwater fishes *Protopterus* and *Polypterus*, and various others, etc. On the other hand, the Bears and Deer and most of the Goats and Pigs are absent from this region. The Oriental Region has the Orang and Gibbons, some of the Lemurs, the Indian Elephant, and Rhinoceroses, sundry large gallinaceous birds, such as the Peacock and Argus Pheasant, etc. The Palæarctic and Nearctic Regions are more alike than any other two. Lacking the animals that we have mentioned as characterizing other regions, they possess the Lynxes, true Shrews, Beavers and other rodents, most of the Oxen and Sheep, Thrushes, Wrens, Tits, Finches, Newts, Sturgeons, Salmon, etc. The Nearctic differs from the Palæarctic in the possession of the Opossums, Skunk, Racoon, Blue Jays, Rattlesnakes, large Newts, and many freshwater fishes, such as *Amia*, *Lepidosteus*, *Polyodon*, and *Scaphirhynchus*.

This scheme, however, like every other that has been suggested, fails for the reason that the distribution of the different groups of animals does not agree, so that a region that coincides with the limits of the distribution of one group cuts across the range of others. Thus South America should be united with Australia if the distribution of marsupials (of which it has a few), and of frogs, is to be expressed, but with North America if regard be had to reptiles and scorpions; Southern Asia is related to the land which lies northward of it and to Australia in its reptiles, to Australia also in its earthworms, and to Africa in its mammals, its frogs, and its beetles: and so forth. Systems of zoological regions are valuable in the study of particular groups of animals: applied to whole faunas they are misleading.

The distribution of fresh-water animals follows roughly that of the land fauna, but, as we have seen, is for various reasons more cosmopolitan. Owing to the continuity of the sea, the constancy and transporting power of its currents, and the relative uniformity of its conditions, marine animals are more widespread than those of the land, their distribution shows more dependence upon simple physical conditions such as temperature and salinity, and hence the difference between the local faunas is less. Nevertheless the oceans and coasts have faunas of their own, though the same difficulty stands in the way of recognizing " regions " inhabited by compact faunas.

CHAPTER XIII

MIGRATION

The reason for the lack of correspondence in the distribution of different groups of animals is not far to seek. It is that the distribution of each depends upon two factors neither of which is the same for any two groups. The first of these factors is the position in which the group arose; the second is its power of spreading. As during the evolution of the Animal Kingdom its several groups arose, they did so in different regions, so that, even if they had had the same facilities for spreading, their distribution would have tended to be different. But the spread of each from its place of origin was accomplished by different means, and was helped and hindered by different circumstances.

Every species has certain normal means of dispersal which enable it to occupy a certain area. That is, of course, a necessity for it. If the offspring of the individual remained where their parent gave rise to them, the species would perish, either by overcrowding or by one of those vicissitudes—the attacks of enemies, changes of temperature, drought, flooding, etc.—which sooner or later make every spot at least temporarily untenable. The normal modes of dispersal include, of course, all those by which locomotion is accomplished, either actively or passively, in the normal life of the species, and it is not necessary here to add to what has been said upon this subject. Many animals have both active and passive distribution. Each of these is often provided by a special stage of the life-history, and may take place only at such a stage, but more usually occurs incidentally throughout life. (*a*) Sessile animals and parasites are dispersed to new individual habitats only in the *distributive phase* which each of them passes through and in which it swims free, or drifts, or is air-borne, and is often unable to feed or to reproduce. Many others which as adults are restricted to the substratum, like echinoderms and crabs, have greater powers of dispersal at an earlier stage in their life-history, unlike those, such as most pelagic animals, ungulates and other mammals, etc., which are equally capable of dispersal at all times. Most often distributive

phases are larval, like the planulæ of corals, the nauplii (Fig. 407) and zoeæ of crustacea, the trochospheres of molluscs and worms, and

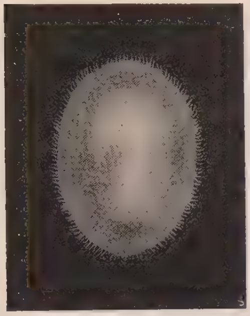

Fig. 384.—The *Planula* larva of the Red Coral (*Corallium rubrum*).—After Lacage Duthiers.

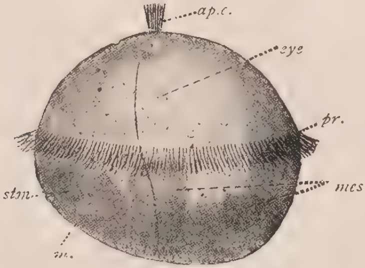

Fig. 385.—The Trochosphere of *Nereis*.

ap.c., Apical tuft of cilia; *eye*; *m.*, opening of mouth; *mes.*, mesoderm; *pr.*, preoral ring of cilia; *stm.*, stomodæum, from which is formed the lining of the mouth and gullet.

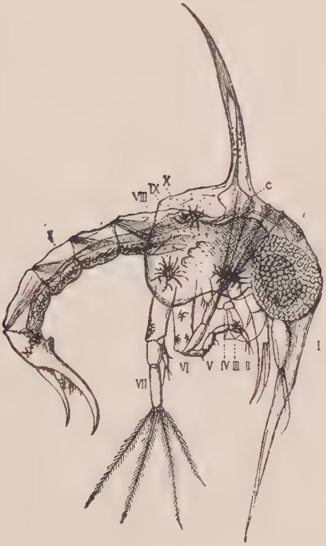

Fig. 386.—The *Zoœa* larva of the Shore Crab (*Carcinus mænas*).—From Thomson, after Faxon.

The numerals indicate the paired limbs.

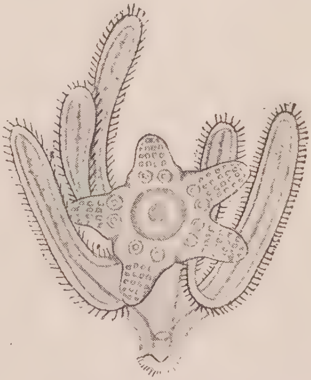

Fig. 387.—The *Pluteus* larva of a brittle star, showing the rudiment of the body of the adult.—From Thomson, after Johannes Müller.

the auriculariæ, bipinnariæ, and plutei of echinoderms. Sometimes they are the adults, like *Heteronereis* and most insects. In other cases they are alternate generations, like the medusæ or jelly-

fishes by which hydroid zoophytes are spread, the sexual individuals of most polychæte worms, and the winged plant lice (Fig. 65). (*b*) *Incidental dispersal* of the active kind is chiefly accomplished by the animal in the course of the perennial search for food, and occasionally more vigorously in consequence of changes by which the habitat becomes relatively unfavourable in comparison with adjoining localities. Only in very temporary and exceptional seasons of plenty is there, for most animals that are active, enough food to support all the young that are born. It is precisely those for which

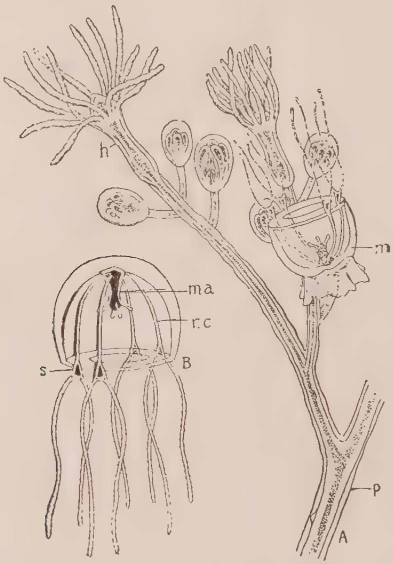

FIG. 388.—Part of a colony (*A.*) of the hydroid zoophyte *Bougainvillea*, with one of its medusæ (*B.*).—From Thomson, after Allman.

p., Sheath or perisarc ; *m.*, young medusa not yet free ; *h.*, hydranth or polyp head ; *ma.*, manubrium ; *r.c.*, radial canal ; *s.*, sense organ.

there is food enough, and whose numbers are kept down only by their enemies, that are inactive, though, as we have seen, even these must have a distributive phase. Save in the period in which they are seeking mates, the waking life of most animals that can move about is spent in a ceaseless quest for food, in which the surroundings are explored by the species in every direction till it reaches limits beyond which lie regions whose conditions do not permit its existence and which cannot be crossed by the means at its disposal. Sooner or later a passively distributed species will also reach such limits.

The area over which a species exists is its *range*, and we have seen (p. 27) that this is sometimes very wide and sometimes (p. 36) very narrow: it should be noted also that most animals cannot dwell in all parts of their ranges, but must settle in certain spots or *stations*, as a bird may inhabit only suitable copses, an insect its food-plant, or a parasite its host. Upon the circumference of its range, a species is constantly pressing. If conditions anywhere allow an extension, advantage is taken of the fact. Further, when in any direction a food supply is available immediately over

FIG. 389.—The Lemming (*Myodes lemmus*).—From Flower and Lydekker.

a natural boundary, members of the species that can in any degree endure the foreign conditions do so temporarily for the sake of the food, as animals for whom the presence of Man makes unsafe the regions he inhabits will raid them from time to time. This will happen even when conditions in the normal home are as fixed as they can ever be in a world of constant change; but in certain circumstances, that are ill-understood, the pressure of an active species upon its boundaries may be intensified, and the animals impelled to push into regions that were before relatively unsuitable. It is thus that there came about the periodical "migrations" of the Lemming, Sand Grouse, Locust, and other animals. The impelling

cause of these has been supposed to be a scarcity of food due to over-multiplication of the species, but it seems that the Locust at least is in no danger of starvation when it migrates. Possibly the process is an expedient for the distribution of the species, of the same kind as the appearance of the distributive phase of parasites and sessile animals. The Lemming (*Myodes lemmus*), a little rodent related to the Voles, lives in the central mountain chain of Scandinavia. At intervals of from five to twenty years it invades the low lands in enormous hosts, and steadily advances,

FIG. 390.—Pallas' Sand Grouse (*Syrrhaptes paradoxus*).—From Newton.

always in the same direction and regardless of all obstacles, even swimming lakes of several miles in breadth, eating all vegetable food on the line of march. It is pursued and decimated by birds and beasts of prey, bears, wolves, foxes, dogs, wild cats, stoats, weasels, eagles, hawks, and owls, and, of course, is not spared by man. Numbers die of disease caused by overcrowding. None ever return, and it is said that the march does not cease till the army reaches the sea, into which it plunges, swimming onwards till it drowns. The Sand Grouse (*Syrrhaptes paradoxus*) dwells in deserts in Central Asia and periodically invades China and Europe in great flights. It has reached even to Ireland, and in

the invasion of 1888 a few bred in suitable places, but it never gained a permanent footing. The swarming of the various species of grasshoppers known as locusts is proverbial. Speaking of their numbers, Sharp says: "Large swarms consist of an almost incalculable number of individuals. A writer in *Nature* states that a flight of locusts that passed over the Red Sea in November 1889 was 2000 square miles in extent, and he estimates its weight at 42,850 millions of tons, each locust weighing one-tenth of an ounce. A second similar, perhaps even larger, flight was seen passing in the same direction the next day. That such an estimate may be no exaggeration is rendered probable by other testimony. From official accounts of locusts in Cyprus, we find that in 1881, up to the end of October, 1600 million egg cases had that season been collected and destroyed, each case containing a considerable number

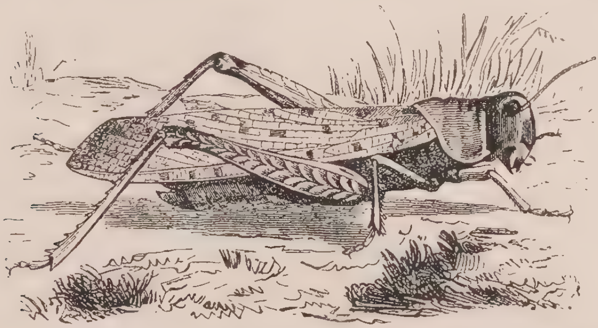

FIG. 391.—The Migratory Locust (*Pachytylus migratorius*).—From Dallas.

of eggs. By the end of the season the weight of the eggs collected and made away with amounted to over 1300 tons, and, notwithstanding this, no less than 5076 million were, it is believed, deposited in the island in 1883." Such is the violence with which, at times, species burst their bounds. Probably, however, the steady continuous pressure of the species on its boundaries is more effectual in establishing it in new localities. If in successive generations, pressing outwards, either in the normal search for food or impelled by some permanent change at home—as of temperature or in the numbers of enemies—some strains of its members make good their foothold, they will have accomplished a true migration, a thing distinct from a temporary outwandering into inhospitable regions.

Often the migrating members of a species become changed in establishing themselves in their new home. This need not happen

if the animals be spreading over a region to which they are well adapted but which they have not yet had time to occupy, or if the conditions be unfavourable to their old mode of life but not beyond their powers of adjustment. In this way, for instance, the naturally shy Wood Pigeon has recently established itself in London. But if their new circumstances be sufficiently different from those in which they have been living, the migrants can only spread at the price of modification. In the one case the range of a species will

FIG. 392.—*Tapirus americanus*, one of the Tapirs of South America.—From Flower and Lydekker.

merely have been extended; in the other a new race or species will have come into being—with a range of its own, narrow at first, but probably widening. Whether the modification be due to the action of the new surroundings or be due to spontaneous variation which enables the animal to exist in such surroundings, is part of a problem with which, as we have seen, we are not concerned. There must, however, be borne in mind the possibility that, by spontaneous variation of the body, or as the effect of a new relation with the surroundings brought about by the spontaneous adoption of new habits, a new race may arise and thrive in some part of the range

of a species in which the conditions are not different from those of the rest, and that thus as it spreads a species may give rise to others without entering new conditions of life.

If a species which has spread without becoming modified become extinct in its original habitat, its range may shift rather than be extended. If, again, a species or higher group die out in the middle of its range, continuing to exist in the outlying parts, its distribution will become *discontinuous.* In the distribution of species discontinuity is rarer than in that of higher groups, though

Fig. 393.—The Malay Tapir (*Tapirus indicus*) and its young. Note the dappled colouring of the latter.

it is not unknown. Between the species of a genus many striking instances of it exist. The Blue Magpies (*Cyanopica*) are found in the Iberian Peninsula and again in North-Eastern Asia; the Tapirs in South America and the East Indies. The family Camelidæ is represented by the Camels in Asia and the Llamas in South America. Of the Great Apes (*Simiidæ*), the Gorilla and Chimpanzee are found in West and Central Africa, the Gibbons in Malaysia, the Orang Utan in Sumatra and Borneo. The Order of the Lung Fishes (*Dipnoi*) contains in modern times only the genera *Lepidosiren* in South America, *Protopterus* in West Africa, and *Ceratodus* in Aus-

tralia. In most of these cases it is known that in former geological periods the distribution of the group was continuous. Competition, a change of climate, or some other unfavourable condition has extinguished it in a great part of its range, leaving it in isolated

FIG. 394.—A map of the distribution of the Tapirs.

colonies. There appears, however, to be another kind of discontinuous distribution which is due to similar animals arising by "parallel evolution" in widely separated regions. It seems likely

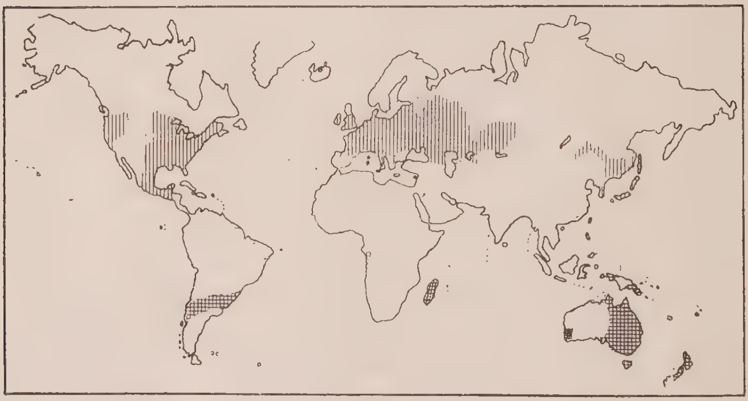

FIG. 395.—A map of the distribution of the Crayfishes.—After Calman.

that the distribution of the Crayfishes, which are found in the North and South Temperate Belts, separated by a wide gap in the Tropics, is thus to be explained.

Looking conversely upon the relation which exists between the

ranges of species and local conditions of life, we may note that the inhabitants of any locality fall into three sets : (*a*) *autochthonous species*, which were evolved on the spot in conditions like those in which they now live there ; (*b*) *immigrants*, which were evolved elsewhere but proved on arrival able to stand the local conditions ; (*c*) *relicts* of a population which dwelt in the locality at an earlier time, which have survived a change in conditions, as the marine members of the fauna of relict lakes have survived the freshening of the waters.

Another kind of migration must be noticed here. Besides the permanent changes of location, there are voyages in which members of a species, without for ever forsaking one habitat, visit some other at a season when it affords a plentiful supply of food, returning either when that supply fails, or for the purpose of reproduction if the second habitat be unfavourable for that process—as it may be for various reasons, either owing to some habit of the animal, as in the case of the Seals, which breed on land, or owing to the lack of suitable food for the young, which is suspected in the case of some birds. In course of time the migration may be pushed farther and farther afield, and if in the meantime intermediate regions become unfavourable to the species, or relatively so, they may be passed over rapidly, so that there are periodical journeys from one habitat to another and back again. The best known examples of these are the seasonal migrations of birds. In spite of the ages for which it has been familiar and the amount of investigation which has been bestowed upon it, bird migration is still an ill-understood subject, and any generalizations which may be made upon it must admit exceptions. It is clear, however, that the practice is almost universal, that the length of the journey varies enormously, that often not all members of a species make the same journey, and that a bird usually breeds in the colder part of its range, but during what is the warmest part of the year. Coward classes British birds in respect of their migration, in which they may be taken as a typical example, as follows :

1. *Permanent Residents* : birds which remain in Britain all the year round. These are comparatively few in number, and largely consist of insular races of birds which perform regular and often long migrating journeys in other parts of their range. Most, if not all, perform short migrations, in some cases only seasonal changes of altitude, spending summer on the hills and winter in the lowlands ; examples, the Red Grouse and Dipper. Others, like the Tits and Creepers, are nomadic and more or less gregarious in the colder months. Few appear to remain in the same locality at all seasons, but possibly some of our British robins and song thrushes, both

sub-species of migratory continental forms, may be non-migratory.

2. *Summer Residents*: birds which nest in our islands, leaving in autumn for countries to the south and returning in spring. In addition to the regular summer visitors, which all leave in autumn, this group includes a number of wagtails, pipits, finches, and other birds which are represented in winter in our islands by a proportion which remain.

3. *Winter Residents*: birds which nest to the north or east of our islands and arrive in Britain in autumn, leaving in spring for their breeding area. With birds like the Fieldfare, Brambling, and Jack Snipe, which do not nest in Britain, here must be included many

FIG. 396.—The Red Grouse (*Lagopus scoticus*).

(for example the Robin, Rook, Song Thrush, and Common Snipe) of which some individuals are permanent residents.

4. *Birds of Passage, or Spring and Autumn Migrants*: birds which neither nest with us nor normally remain for the summer, but merely use the British Islands as feeding and resting places on their journey between the northern breeding area and the southern or eastern winter quarters. In some of the species of this group certain individuals breed here.

5. *Irregular Migrants*: spasmodic and occasional invaders, such as the Sand Grouse.

6. *Stragglers or Wanderers*: birds whose occurrence is due to their having lost their way.

It appears also: that young and old birds travel sometimes

together and sometimes separately, so that the journey may have to be made for the first time without guidance; that some species fly by day and some by night, and that in other cases the flight is kept up day and night; that the birds do not always follow the route along which the migration originally developed, but may take short cuts over land or sea; that they often follow coast lines or river valleys, especially if they be day migrants, who probably in this way guide themselves by sight; that in many cases it is impossible to explain their finding their way except on the supposition that they possess in a very high degree the sense of direction which exists in many animals and even to some extent in Man, and is possibly in some way connected with the semicircular canals of the ear; that they fly at considerable heights, often at

FIG. 397.—The American Golden Plover (*Charadrius dominicus*).—From Baird, Brewer, and Ridgeway.

some thousands of feet, where they probably find the air-currents steadier and may avail themselves of those that set in the right direction; that they sometimes fly at immense speeds (the Golden Plover is said to be able to cover 150 to 200 miles per hour in favourable circumstances); and that some of them can take very long journeys without rest, perhaps by using the currents of the upper air. The length of the voyage varies from a few miles to thousands. Storks marked in Prussia have been taken wintering in the Transvaal. The American Golden Plover (*Charadrius dominicus*) nests along the Arctic coasts from Alaska to Hudson Bay: it winters in Argentina, after a roundabout flight of 2500 miles which passes through Labrador and Nova Scotia, with rests and feeding in each of these places, then direct across the sea to Guiana, and thence, after a further rest, over Brazil. The return route is a straighter one.

Among mammals migration is known to take place in the Reindeer, North American Bison, South African antelopes, certain bats, whales, and the dolphin *Delphinapterus leucas* (the "White Whale"), which regularly ascends the Amoor River to a distance of 400 miles on

FIG. 398.—A map of the migrations of the American Golden Plover.—From Coward.

the breaking of the ice. These migrations are purely for the sake of food. Various seals, however, return regularly from long distances to certain spots to breed. The Fur Seal of the North Pacific (*Otaria ursina*) breeds in the summer in the Pribyloff Islands, and makes a journey of 1500 miles thither from the coast of California, where it spends the rest of the year. Many fishes, both freshwater and

marine, undertake seasonal migrations. In these they appear to seek waters of a certain temperature and salinity, less, perhaps, for

Fig. 399.—The Fur Seal (*Otaria ursina*) on its breeding grounds.—From *Cassell's Natural History.*

any direct effect of these factors upon the adult fish than for their influence on the one hand upon the smaller animals which serve

the species for food, and on the other upon its delicate eggs and larvæ. Thus at the spawning season cod collect in the regions of the North-West Atlantic where, at the junction of the cold, relatively fresh waters of the northern currents and the warm, saline waters from the south, there are certain precisely suitable conditions. In the same way the herring which collect from adjoining waters upon our coasts appear along the east coast of Britain, from the Orkneys in May to the coast of Cornwall in December, with the passage of a certain temperature and salinity of the water. The Tunny, which has a world-wide distribution, arrives in May off the Straits of Gibraltar and passes into the Mediterranean in great numbers. In August it again scatters over the ocean. Of freshwater fishes, some, as trout, in the spring leave the large rivers for brooks, where they spawn. Others, as salmon, shad, and sturgeons, feed and

FIG. 400.—The Tunny (*Thynnus thynnus*).—From Boulenger.

mature in the sea, but ascend rivers to spawn, and in many cases afterwards to die. The great King Salmon of North-West America (*Oncorhynchus*) travels distances which are, in the Yukon, as much as 2000 miles from the sea to its spawning beds. Such species are said to be *anadromous*. Those which migrate in the opposite direction, to spawn in the sea, are *katadromous*. These are less numerous. The best known example is the Common Eel which, from north-western Europe, makes its astounding migration of 2000 miles to spawn in deep water south of Bermuda, swimming against the North Atlantic Drift and Gulf Stream. The adults do not return. The young are borne by the currents just mentioned on the return journey, during which they undergo their remarkable metamorphosis, starting as the Glass Fish (*Leptocephalus*), which has even more than the common transparency of pelagic animals, and reaching the coast as small, eel-like elvers which travel up the rivers.

The barriers which limit the distribution of animals are of various kinds. (i) The most effective are wide stretches of water for land animals, and land for inhabitants of the water. For shallow water animals, deep water too wide for them, as adults or larvæ, to survive the passage over it, is also a barrier. (ii) Mountain ranges are important, but those which lie east and west, as most in Europe and Asia, are more efficient than those which, as in America, run north and south. The Himalayas, for instance, separate more different faunas than the Rocky Mountains. This, no doubt, is because ranges which are parallel with the equator sharpen climatic differences which would exist without them, while the others do not. (iii) Regions of uncongenial physical conditions, as of tempera-

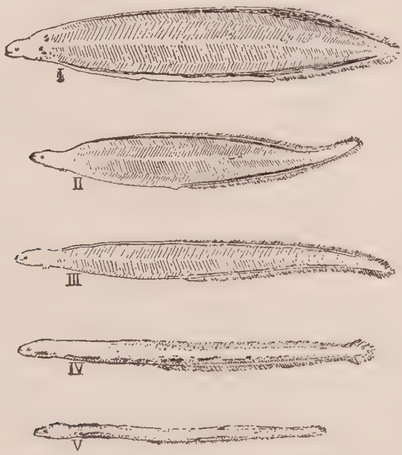

FIG. 401.—The development of the Eel.—From Thomson, after Smit.

ture, moisture, or salinity of water, will prevent the spreading of animals. (iv) The presence or absence of certain types of vegetation may also be a barrier, both by affecting the food supply of herbivorous and indirectly of carnivorous animals and in other ways, as a forest belt is untraversable by many animals, but its absence prevents the migration of arboreal creatures.

A further complication of the factors which limit the distribution of animals is introduced by the fact that barriers have changed continually during the course of organic evolution, so that not only have groups which arose in different places a different distribution, but those which arose in the same region at different times have found their spreading hindered by different sets of barriers. The history of the land masses of the globe is an obscure

and much-debated subject. We may, however, here outline a view which is adopted by many authorities, and which seems best to explain the distribution of animals. During Palæozoic times, very roughly speaking, there were two great land masses,

FIG. 402.—A map of the World, showing the distribution of land and water, which, according to some authorities, existed in Upper Cretaceous times.—From Gadow. The darkened regions represent water.

a northern and a southern, separated by a sea across which from time to time causeways arose and disappeared. The northern land mass corresponded to the present continents of Europe, Asia, and North America, and extended across the northern part

of the North Atlantic. With many vicissitudes, and the appearance and disappearance of many breaks in its continuity, especially in that part of it where Europe now lies, this circumpolar land has remained till the present day, and is now the central mass or hub of the world's land, as a wide ring, with a gap in the North Atlantic, but only just broken at Bering Straits. The southern land mass included South America, Africa, Southern Asia, the East Indies, and Australia, with—according to some authorities—land which joined them across the South Atlantic and Indian Oceans. Later,

FIG. 403.—A map of the World, to show the mass of land around the North Pole, and the three southward projections from it.

at all events, it was connected with the Antarctic continent, both through Australia and through South America. In Cretaceous times it began to break into continents that eventually became South America, Africa, Southern Asia (which suffered a good deal of submergence), and Australia, which was early separated from South Asia. During succeeding ages the first three of these masses gradually became joined, with many fluctuations of the connections, to the northern land mass, so that there is now a central hub with three spokes extending southwards as South America, Africa, and Southern Asia, from which the East Indies reach towards Australia.

It was in the northern land mass that most of the principal groups of the Mammalia, and probably of other land animals also, arose; though some, such perhaps as the Onychophora (*Peripatus*) and earthworms took origin in the south. Through the fleeting connections of the southern continents with the northern land-mass, those continents received from the north the ancestral stocks from which, during their separation, they evolved their peculiar animals.

In the long run, however, most barriers prove but partly effective. From time to time there occur, for animals which they normally restrain, occasions of surmounting them, either by active locomotion or by being passively transported. Such wanderers, if they reach a region where conditions suitable to them prevail, may find the ground already occupied by a native competitor and be unable to make good their footing. If they do so, their isolation and the inevitable differences between their new habitat and that in which they were evolved must presently result in their transformation. But the higher group, if not the species or genus, will have invaded the new region. The means of occasional dispersal of animals may be provided by various circumstances. (i) Land bridges and water channels may put larger masses of their elements into communication. The isthmuses of Panama and Suez, and that which formerly united Asia with North America across the Bering Strait, have been of great importance in the formation of the faunas of the continents. The interruption of communication between North and South America had as a result the isolation of the latter, while a great part of its characteristic fauna was being evolved. When it was re-established it enabled, among other northern forms, the Llamas to spread from North America, where the original ancestor of these animals and the Camels arose, southwards. Across the Bering Straits causeway the forebears of the true Camels reached Asia, and across the Isthmus of Suez they passed into Africa. Bears and the ancient Elephants (Mastodons and Mammoths) passed from Asia into America by the same connection which the Camels traversed in the opposite direction. If it were not for the Bosphorus and Dardanelles, the Black Sea would become a relict water as the Caspian Sea has done, and former breaks in the isthmuses of Panama and Suez are responsible for certain resemblances in the water faunas which they now separate. (ii) Ice bridges allow such journeys as that of Nova Zembla reindeer to Spitzbergen. (iii) Rafts formed by ice or driftwood will carry animals for long distances, if they be able to stand starvation and splashing with salt water. Single trees, or masses of entangled vegetation, will travel for long distances, and may bear a consider-

able assemblage of arboreal mammals (monkeys, squirrels, cats, etc.), reptiles, molluscs, and insects. They have been seen hundreds of miles from land, and have been often known to have disembarked passengers safely. Probably, however, their importance has been greatly overrated, for it is only in the most exceptional circumstances that the emigrants they carry could make good. (iv) The many small aquatic animals that are capable of surviving in dried mud by the expedients that we have noted, can be and undoubtedly often are transported upon the feet of water birds. This has been proved by experiments upon mud taken from the feet of birds that have been shot. (v) Gales will convey as dust the same animals that can be transported in mud, and currents will distribute various aquatic animals, marine and fresh water. (vi) Needless to say, animals which have the power of flight are able to traverse obstacles of all kinds, and though this is probably rarely done intentionally save by those birds which make a habit of migrating along fixed routes, yet these and other flying creatures may be blown for very great distances. Thus a case is quoted in which a ship encountered, at a point 960 miles south-west of the Cape Verde Islands, "some hundreds of moths belonging to a species which is common in the Eastern tropics, but not found in South America, which was the nearest land. From the direction of the wind during the four days previous to the occurrence, it appeared to be beyond doubt that the insects had come from the islands named, and therefore must have crossed nearly a thousand miles of ocean!" The landing of American birds upon our coasts after heavy storms is not unusual.

The relative effectiveness of the modes of spreading possessed by various groups is well illustrated by the faunas of islands. These pieces of land have arisen in two ways: either they are detached portions of continents, as are Britain, Japan, Madagascar, and New Zealand; or they have taken origin in the ocean by volcanic upheavals or the growth of coral reefs, as the Maldives, the Sandwich Islands, etc. It is found that oceanic islands, which must, of course, have received all the members of their fauna by passage over sea, are without mammals other than bats, amphibia, or, except in a few instances in which they may have been introduced or the status of the island is doubtful, earthworms. Most other groups of land animals may be represented in them. Now Amphibia are quite intolerant of sea water, so are earthworms and their cocoons, and land mammals cannot stand the long exposure of a sea voyage without food. The powers of swimming of some of them are good, but none are equal to travelling in that

way for long distances. Bats have, of course, means of passing over the sea, and that they are comparatively few in oceanic and some continental islands is probably due to lack of food, owing to the tendency to lose the power of flight which, as we have seen, is

Fig. 404.—The New Zealand Short-tailed Bat (*Mystacops tuberculatus*).—From *Cassell's Natural History*.

found in insects as well as in birds in certain islands. It is suspected that one of the New Zealand bats (*Mystacops tuberculatus*), which has sharp claws of peculiar, shape and wings which fold very close under a protecting membrane, seeks its prey by crawling upon the

A B

Fig. 405.—The thumb (*A.*) and the leg and foot (*B.*) of the New Zealand Short-tailed Bat.—From Flower and Lydekker.

trunks and branches of trees. Of continental islands it is noted that those which are older have a fauna which is less like their mainland than that of those which are younger, as the fauna of Britain resembles that of Europe more than that of Madagascar resembles the African fauna.

CHAPTER XIV

INTERNAL PARASITES

It remains only that we should deal with the last of the great faunas, that which is constituted by the internal parasites. External parasites are members of the faunas to which their hosts belong, bathed in the same medium and subject to the same conditions

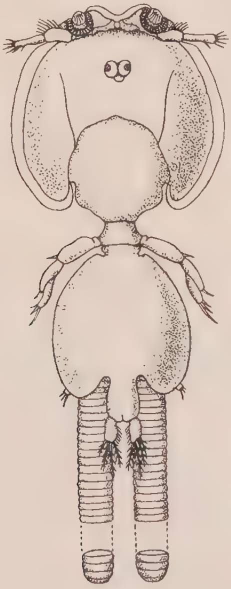

Fig. 406.—*Caligus minimus.*—After Scott.

A parasitic copepod found both in the mouth and upon the under side of the gill cover of the Bass.

of temperature, salinity, and so forth. Internal parasites have a medium of their own, which is a fluid of the body of the host; a substratum of their own, which is some internal tissue of the host; and an external temperature, which is the internal temperature of the host, and thus even in cold-blooded animals often differs

slightly from that of the outer world, and in warm-blooded animals not only differs greatly, but is almost constant. Yet between the two classes it is hard to draw a line. A worm which, living in the intestine of its host draws its nourishment from the wall, is an internal parasite. Must we not say the same of a fish-louse which lives in the same way in its host's mouth ? And if so, what is the status of a similar crustacean attached to the gills ? Are we to distinguish between this and a like crustacean which is attached to the skin, by a quibble based on the fact that the gills are endodermal structures ? Again, where is the line to be drawn in such a series as that

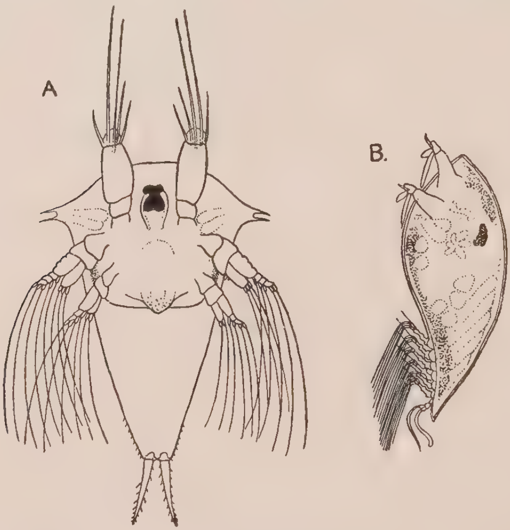

Fig. 407.—Free-swimming stages of *Sacculina carcini.*—From Calman, after Delage.

A., *Nauplius* (first larva) ; *B.*, *Cypris* larva (second stage, which fixes).

of the parasitic copepods of the Ascidicolidæ, which begins with *Notodelphys*, a good swimmer that leaves the pharynx of its ascidian host at will, continues with the more degenerate *Doropygus* (Fig. 236) lodged permanently in the pharynx, and ends with degraded intestinal parasites like *Ascidicola* and *Enterocola* ? Yet again, what is the status of *Sacculina*, a degenerate barnacle which starts by settling upon the body of a crab, passes into the interior, and eventually, by growth, comes to project externally as a sac, hanging on only by the stalk which leads to its internal roots ; or of the isopod *Entoniscus*, which penetrates from the gill-chamber deep into the body of a crab, but remains covered by the skin, which it pushes before

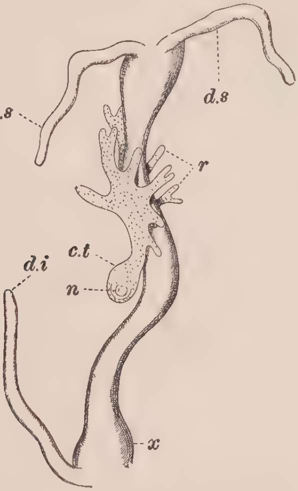

FIG. 408.—A young *Sacculina* in the internal stage, lying against the midgut of its host.—From the *Cambridge Natural History*.

c.t., Central tumour of the parasite; *di.*, *ds.*, anterior and posterior diverticula of the alimentary canal of the host; *n.*, "nucleus" or body-rudiment of the *Sacculina*; *r.*, its roots; *x.*, definitive position of parasite.

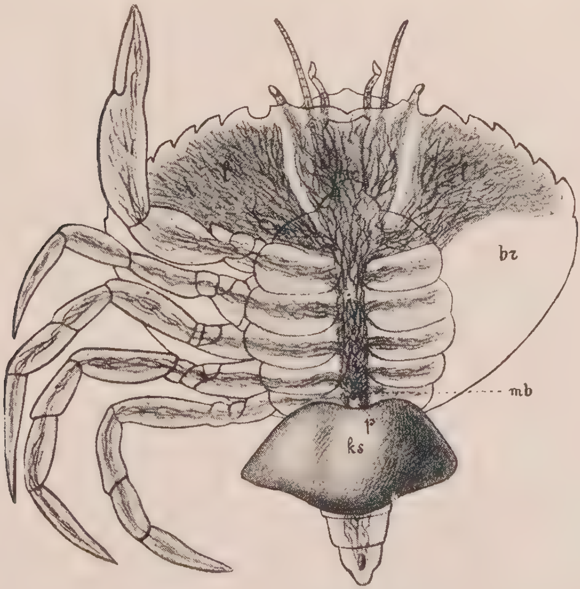

FIG. 409.—*Sacculina carcini*, a parasitic barnacle, *in situ*, on its host, a shore crab. Semidiagrammatic.—From Lang.

br., Branchial region of the crab; *d.*, hepatic region; *ks.*, body of the *Sacculina*; *mb.*, basilar region from which the roots of the parasite proceed; *p.*, its peduncle.

it? It is necessary to recognize that there is a set of animals which bears to the internally parasitic fauna much the same relation that the amphibious fauna bears to that of the land.

Most of the groups of animals which furnish external parasites have also members that have become internal in their hosts; and

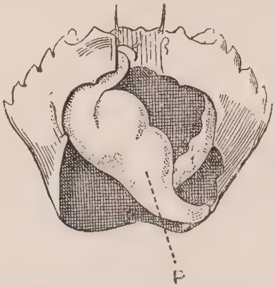

FIG. 410.—The carapace of a shore crab, seen from the ventral side, with a parasitic isopod (*Portunion mænadis*), which has pushed in the lining of the gill-chamber. From the *Cambridge Natural History*, after Bouvier.

probably the one fauna is as large as the other. Parasites, as we have already noted, though they are extremely numerous, are much less familiar than other animals. Properly to describe the fauna with which this chapter deals would require far more space than is

FIG. 411.—*Entamœba dysenteriæ* (=*E. histolytica*), a dangerous parasitic amœba of man.

a. and *b.*, Amœbæ as seen in fresh stools; *c.*, an amœba as seen in a fixed preparation.

at our disposal. We shall therefore content ourselves with stating some facts of importance about it, alluding only to such examples as are likely to be known at least to the student of zoology. On p. 104 the characteristics which are shared by internal parasites with those that are external are enumerated. There are others which belong principally or solely to the internal species.

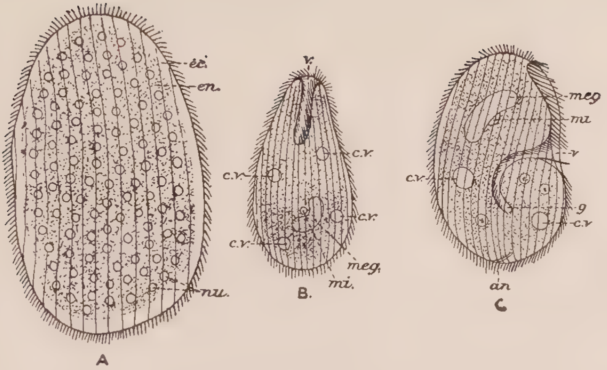

FIG. 412.—Ciliata from the rectum of the frog.

A. Opalina ranarum; B., Balantidium entozoon; C., Nyctotherus cordiformis. an., Anus; *c.v.*, contractile vacuoles; *ec.*, ectoplasm; *en.*, endoplasm; *g.*, gullet; *meg.*, meganucleus; *mi.*, micronucleus; *nu.*, nuclei; *v.*, vestibule or peristome.

FIG. 413.—Species of *Monocystis* (Sporozoa) parasitic in the vesicular seminales (parts of the cœlom) of earthworms.

A., M. magna; *B., M. agilis.* The latter is covered with the tails of spermatozoa, the offspring of the sperm mother-cell in which it was embedded.

Internal parasites live in various parts of the bodies of their hosts. They may reside: (i) in the hollows of the body, as *Entamœba*, ciliates, tapeworms, and nematodes in the gut, the Liver Fluke in the bile-ducts, *Monocystis* in the body cavity, and *Trypanosoma*

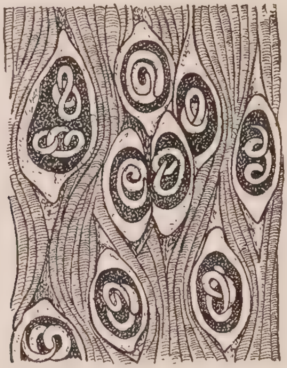

FIG. 414.—*Trichinella spiralis*, young encysted in muscle of host.—From Thomson, after Leuckart.

(the flagellate protozoon which causes sleeping sickness) and the nematode *Filaria* in blood vessels and lymph spaces; (ii) in the tissues, as the Guinea Worm (*Dracunculus*) beneath the skin, and young *Trichinella* in the muscles; or (iii) in protoplasm, as the

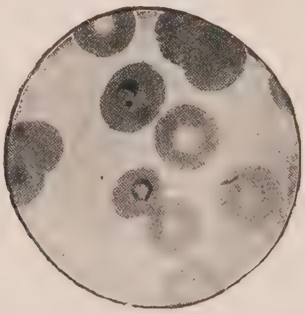

FIG. 415.—Human blood, containing in the red corpuscles individuals of the Malaria Parasite (*Plasmodium vivax*), which causes Tertian Ague. The parasite is in the young, "signet-ring" stage.

young trophozoite of *Monocystis* in sperm mother-cells of the earthworm, that of the Malaria Parasite (*Plasmodium*) in red blood-corpuscles, and *Sphærophrya* in *Paramecium*. They may get their nutriment (i) by devouring other inhabitants of the gut of their host, or (ii) by swallowing undigested particles of its food: probably these methods are usually combined, as by *Entamœba coli* and

ciliates of the gut. Or (iii) they may absorb substances digested by their host, as does the Tapeworm ; or suck its juices, as do the Liver Fluke and many parasitic copepods ; or devour its tissues, as the Miner's Worm browses upon the intestinal villi.

The outward organization of internal parasites is, as a rule, more degenerate than that of the external, and there is often a loss even of means of attachment, the body becoming of a simple flat or cylindrical shape with a smooth surface. The life-history is usually complicated. There is a *multiplicative phase* in which the parasite takes advantage of the rich supply of food in its host to bring forth many offspring—a tapeworm, for instance, has been estimated to produce 80 million eggs—and a *distributive phase*, in which temporarily non-reproductive individuals find new hosts. These phases may both be passed through in the lifetime of a single individual, but more often occur in alternate generations. The distributive

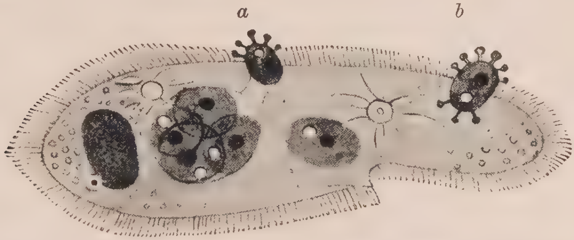

FIG. 416.—*Sphærophrya pusilla*, a suctorian parasite of *Paramecium*. —From Doflein.

a., An individual escaping from a cavity in which it has been formed by division. As it escapes it is developing tentacles, which are lacking in the parasitic individuals ; *b*., an individual entering the host.

phase may be active, as the *miracidium* larva of the liver fluke and the *nauplius* of *Sacculina* (Fig. 407) ; or adapted to passive transmission, as the gamonts of the Malaria Parasite or the tough-shelled eggs of worms. Parasitism may take place at various stages of the life-history. Thus *Sacculina* and the Miner's Worm are free as larvæ, parasitic as adults. The Rain Worm (*Mermis nigrescens*) whose larvæ live in grasshoppers, and the Pond Mussels (*Anodonta*), whose young inhabit the skin of fishes, are parasitic in their early life. Many species are parasitic in two hosts, in different phases. Some of these have a free stage, as the Guinea Worm, whose young, escaping from the abscess in the human host, pass through the water to invade a crustacean o fthe genus *Cyclops* (Fig. 152), which being swallowed reinfects man ; and the Liver Fluke, which passes from the Sheep to a water snail as a free swimming larva, and returns to the Sheep by leaving the snail and encysting upon grass, which

the sheep eats. Others pass directly from the body of each host to that of the other, as do the Malaria Parasites, sucked up and again injected by a mosquito, and the Sleeping Sickness

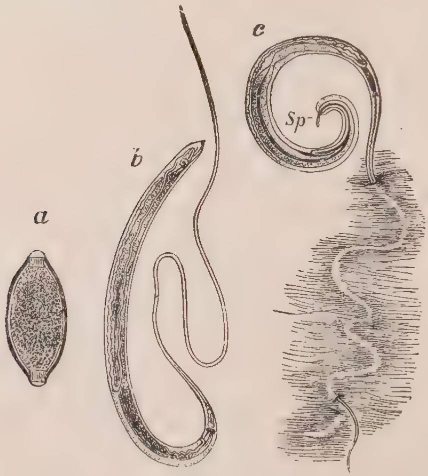

Fig. 417.—*Trichocephalus dispar*, a nematode parasite of the human intestine, transmitted by eggs.

a., Egg; *b.*, female; *c.*, male, with forepart of body buried in mucous membrane of host; *Sp.*, penial seta.

parasite (*Trypanosoma*) transmitted by a tsetse fly. Where there are two hosts, the *principal host* is that in which the parasite passes its sexual phase, if it have one. This, which is not necessarily the

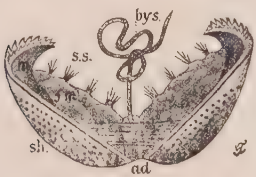

Fig. 418.—The *Glochidium* larva of the Swan Mussel (*Anodonta cygnea*).—From Taylor.

ad., Adductor muscle of shell; *bys.*, byssus by which the larva is attached to the fish until the movements of the latter bring the teeth of the shell against the skin of the host; *s.s.*, cells with sensory processes; *sh.*, shell.

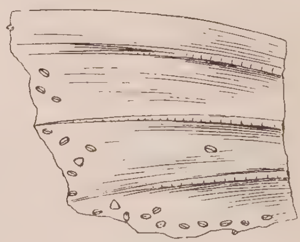

Fig. 419.—Glochidia embedded in the fin of a fish.

larger, usually preys upon the *intermediate host*, but sometimes, as in *Filaria bancrofti*, the reverse happens. Thus the intermediate host of the Malaria Parasite is Man, that of the pork tapeworm is

PLATE IV.

Glossina palpalis, the Tsetse Fly, which carries *Trypanosoma gambiense*, the Sleeping Sickness Parasite.

the Pig, that of *Filaria* is a mosquito, that of the Guinea Worm is *Cyclops*. The advantages of this arrangement are twofold; the

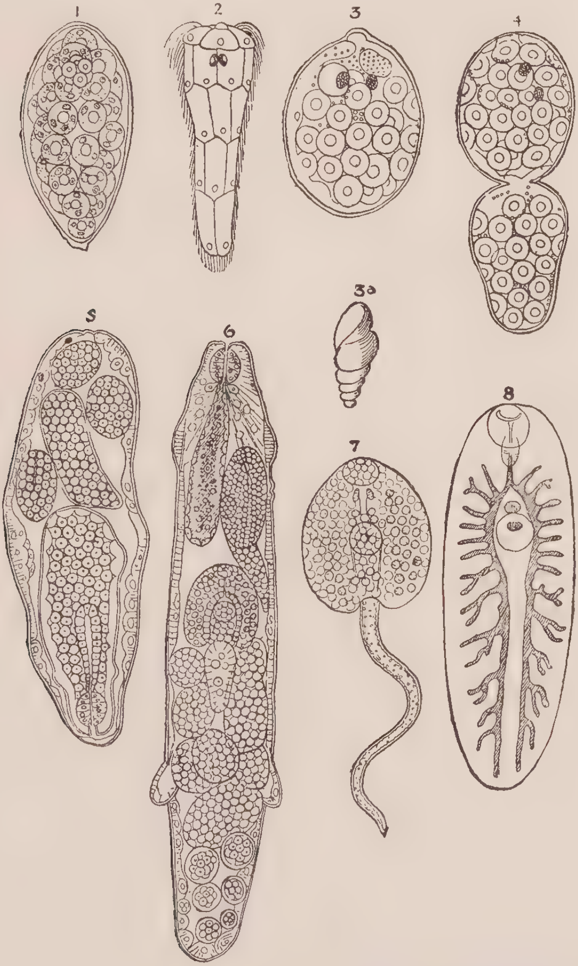

Fig. 420.—The life-history of the Liver Fluke.—After Thomas.

1, Developing embryo in egg case; 2, free swimming ciliated larva (*Miracidium*); 3, sporocyst, into which the larva develops after it has entered the water snail *Limnæa truncatula* (3*a*); 4, division of the sporocyst; 5, sporocyst with a new generation (*rediæ*) forming in it; 6, redia with more rediæ, and also cercariæ forming in it; 7, free cercaria, which leaves the snail, encysts on grass, and is eaten by a sheep in whose liver it becomes 8, a young fluke.

parasite finds a means of re-entering its principal host; and very often the intermediate host provides a richer supply of nourishment than that in which the sexual phase occurs, and the parasite there

undergoes most of its growth and reproduces asexually. When this happens there is an alternation of generations corresponding to the

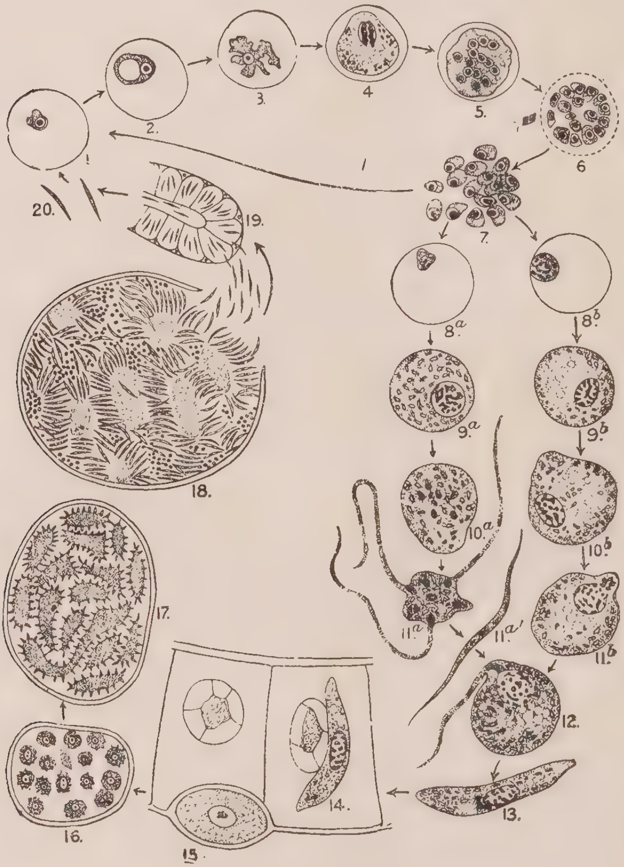

FIG. 421.—The life-cycle of *Plasmodium vivax*.

1–7, Merogony, asexual reproduction which takes place in man; 8–13, gamogony, or sexual reproduction, which takes place in the stomach of a mosquito; 14–20, sporogony, asexual reproduction in the body cavity of the mosquito.

1, Infection of a red corpuscle; 2, signet-ring stage; 3, amœboid stage; 4, full-grown meront preparing to divide; 5, multinucleate stage; 6, rosette stage, corpuscle breaking up; 7, free merozoites; 8, infection of red corpuscles by young gamonts; 9, full grown gamonts free in the mosquito's stomach; 10, 11, formation of gametes; 12, conjugation; 13, zygote; 14, invasion by zygote (sporont) of endoderm cell of mosquito; 15, encystment; 16, sporoblasts formed by division of sporont; 17, 18, formation of sporozoites; 19, invasion by latter of salivary gland; 20, sporozoites injected into blood of a man.

alternation of hosts. In other cases, as in *Filaria* and the Guinea Worm, the intermediate host is merely a means of transport, and no reproduction takes place in it. In yet other cases, as in *Trichinella*,

though transmission is direct, the successive hosts belong to similar, or even by cannibalism to the same species, and the same cycle is passed through in each.

We have already described the way in which many internal parasites, like other animals which live where free oxygen is lacking, contrive to obtain their energy by the decomposition of carbohydrates.

Internal parasites harm their hosts not merely (i) by the abstrac-

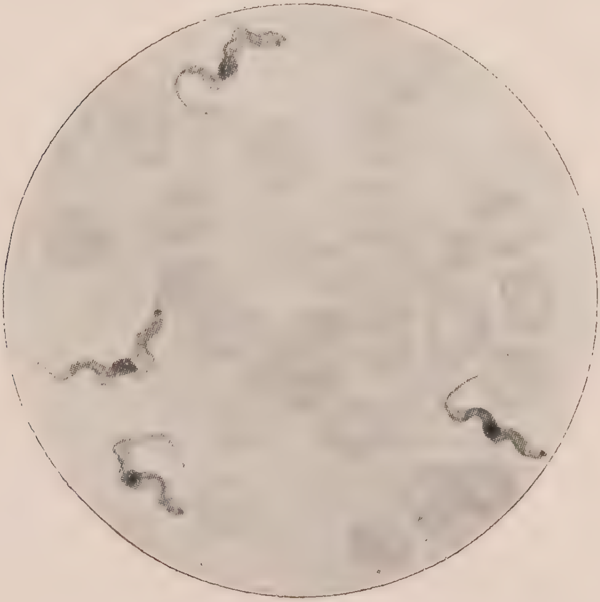

FIG. 422.—*Trypanosoma gambiense.*

A stained preparation of the blood of an infected guinea-pig, showing blood corpuscles and parasites.

tion of their blood or the destruction of their tissues for food, but in other ways also. (ii) Those which live in the alimentary canal may rob the animal of a portion of its food. This is only of importance when the parasite is relatively large, as tapeworms are, and even then is perhaps not the most serious part of the damage. (iii) In very many cases the parasite produces in the course of its life substances, known as *toxins*, which are, accidentally, poisonous to the host. This is done, not merely by Protozoa such as the malaria and sleeping sickness parasites, but also by many worms. The host fights the intruder in various ways. (i) It may enclose it

in a cyst. (ii) It may attack it with leucocytes which devour it. (iii) It may secrete counter-poisons by which it is destroyed. (iv) It may secrete substances which combine with, and so neutralize, the poison. The protective substances which are thus secreted by organisms are known as *antibodies*. Some of them unite directly with the poisons secreted by the parasites and in so doing deprive them of their harmful qualities. They are known as *antitoxins*.

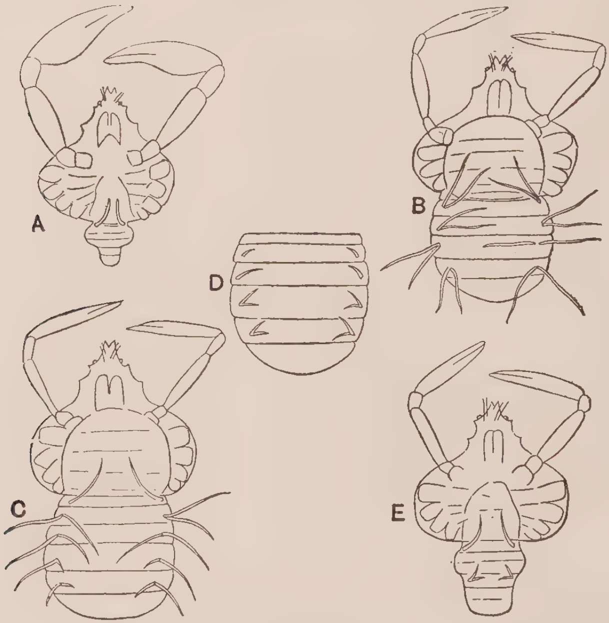

FIG. 423.—Sketches of crabs of the species *Inachus mauritanicus* to show the effect upon them of the parasitic barnacle *Sacculina neglecta*.—From the *Cambridge Natural History*.

A., Normal male ; *B*., normal female ; *C*., male infested by *Sacculina* (final stage) ; *D*., abdomen of an infested female ; *E*., infested male in an early stage of its modification.

Others act by forming a link between the invading organism and a substance present in the normal body of the host and known as a *complement* ; the complement thus aided being able to destroy the parasite. An animal which by the formation of antibodies has protected itself against the attacks of a parasite is said to be *immune* to it. (v) Finally, it is to be presumed that animals which remain unharmed by a parasite which removes a large part of the nutriment from the alimentary canal of its host, do so on account of their exertions in obtaining an extra supply of food.

More remarkable even than the chemical defence of the host, is the "parasitic castration" which is brought about in decapod crustaceans by the attacks of certain Crustacea of other groups. *Sacculina* and the parasitic barnacles related to it, and *Bopyrus* and other parasitic isopods have upon a large percentage of the males of crabs, hermit crabs, etc., upon which they become parasitic, the extraordinary effect of causing them to assume the external character of the female, such as her broad abdomen, egg-bearing abdominal appendages, and shape of chelæ. In females, though the ovigerous appendages may atrophy, there is no tendency to assume any male organ. In both sexes the reproductive glands atrophy. If the crabs recover, the females assume their ordinary organization. The males develop from their testes hermaphrodite glands, producing both ova and spermatozoa. It appears that by some means the parasites produce in the male the female type of metabolism, that this is of advantage to them in enabling them to obtain from the blood the nutriment which the female normally stores in her ova as yolk, and that incidentally it is accompanied by the development of the external features of the female.

CHAPTER XV

THE INFLUENCE OF THE SURROUNDINGS UPON THE ANIMAL ORGANISM

The animal organism not only acts, but is acted upon by its surroundings. In almost every observation that we have so far made upon it, we have regarded it as an agent of change in the world. We have seen it amid various circumstances, favourable and unfavourable, taking advantage of some and overcoming others, propagating its kind, seeking new habitats and adopting new modes of life, changing during its own life and bringing into the world new kinds of animals by the congenital variation in its offspring—always active for its own advantage and that of its race, and in the process effecting changes, often very considerable, in its surroundings. We have, however, given little attention to it as a thing acted upon by its environment. Yet this aspect of the organism, though it is less striking, is philosophically little less important than the other.

Both the forming and the functioning of the individual are influenced from without. This is obvious enough from the fact that its structure and activity vary with its surroundings. Only through some influence of the surroundings themselves could such a correspondence arise. That we can dismiss this influence in a short chapter is due solely to the fact that we have already studied many of the phenomena in which it is exhibited. For it consists in these three things: (*a*) that some at least of the features of individuals arise in them under the action of their environment, of which fact we have noted certain examples; (*b*) that the place and manner of life of every individual are dictated by the world around it to precisely the degree to which it possesses that adaptation to the peculiarities of some particular set of circumstances which we have found throughout the foregoing part of the book to be the means whereby animals exist; (*c*) that a great deal of its functioning conforms to the changing exigencies of its surroundings after a manner which is clearly due to stimuli received from without, and which we have observed in various instances.

It must not be overlooked that the potentialities which are

aroused in the development and in the activity of the individual are such as the surroundings have allowed to be established, or perhaps have established, in its race, nor that behind all this stands the endowment of physical properties which living matter derives from the lifeless world from which it arose. Thus a complete view of the dependence of the animal upon the world in which it lives comprises an historical factor, as well as a subordination to influences in the present.

The dependence of the organism upon its environment may now be more thoroughly analysed.

(*a*) It is for us a little beside the point, since we are concerned with the relation of the individual animal to its immediate surroundings, but it is none the less important, to realize *what, historically, the organism owes to the world* in which it has arisen. (i) *It is by origin altogether a part of the world*, not only in it, but of it, bone of its bone and subject to its laws, even though it is able, in virtue of peculiar powers, to turn these to its own advantage. For it is certain that living matter arose from what was lifeless (in the sense in which we have used that term), and that it is continually taking lifeless matter into itself; and the new properties which appear in the substance of living bodies are there added to properties which are evident in lifeless matter. We can recognize clearly enough in living matter, by their characteristic properties, many substances which exist also in lifeless nature, true though it be that a number of them are only known to be formed under the influence of life; and all alike are subject to forces which also dominate lifeless matter. In the working of the living body we can trace effects of gravity, heat, light, electrical, chemical, and molar energy, even though these forces are directed to the advantage of the body in which they occur, in a way in which they are not directed in lifeless objects, and though there are processes in that body which, as yet at least, we cannot refer to any of them. (ii) With whatever initiative organisms may have been endowed at their origin, *they have not escaped continuous moulding by their surroundings*, during their evolution. On the question how this moulding may have been effected, there are, indeed, the two schools of thought to which we have alluded (p. 8), the one regarding the organism as wholly plastic under the influence of its surroundings, and as transmitting by heredity the changes which they induce in it, and the other holding that the origin of heritable variations of the organism is from within it, and that the environment decides only whether they shall survive; but both alike concede to the world some part in the adaptation of organisms to itself.

(*b*) It is of equal importance that *life is only possible in surroundings which fulfil certain conditions*, both general, for all organisms (p. 5), and special, for each several one. We may here distinguish *cases in which this influence of the surroundings is merely permissive* from others, with which we shall be concerned in later paragraphs, in which it is due to a direct action upon the organism. Thus the presence of food is a necessity for all organisms, but it is not upon all of them that it has also an indispensable direct action as a stimulus to feeding. The feeding apparatus of a ciliate protozoon, for instance, is not so set in motion, but works continuously, whether food be present or not. Only after the body has by its own initiative availed itself of the supply of food does the latter affect it (by influencing metabolism). The presence of food is here a permissive but not a causative condition of the surroundings. Again, a watery medium is necessary for aquatic animals, but for those which have an impermeable covering it is a permissive condition only, enabling them, for instance, to move and feed, but exercising no direct influence upon their physiology. Temperature, on the other hand, whose influence upon organisms is equally decisive, always exercises it by directly affecting their activity, either, as in warm-blooded animals, only through the sense organs, or in cold-blooded animals, also by conduction to the protoplasm.

(*c*) Besides these historical and permissive relations of dependence, from its earliest moment to its last *the individual organism is directly acted upon by its immediate environment.* In part that action is necessary to the animal, and is among the conditions which, as we have already noted, the surroundings must fulfil if life is to be possible in them ; in part it may be regarded as indifferent ; in part it is injurious ; but no individual is exempt from it. (i) Development is directed from within the organism, but it is contingent upon certain conditions. It is due to a property of the developing organism, and of each part of it, of growing in a certain way in certain circumstances. If these circumstances be not present, development cannot take place. Their presence is dependent partly upon external forces. The process will only begin when certain influences are exerted upon the organism by its surroundings, and is affected by such influences from youth to old age. The whole constitution of the individual is due, not only to the properties inherent in it when it comes into being by fission from its parent, but also to influences of temperature, light, gravity, moisture, salinity, and so forth, to which, from the first, it is continually subjected. The peculiar features of a bird are due to the warmth which bring about its formation in the egg, as well as to those

factors in the egg which cause it when it is warmed to give rise to a bird. It is clear from the nature of these conditions that some of them at least must act directly upon the living matter. Their part in causing development consists in bringing the protoplasm into a state in which its mechanism for that process will function. The hen's egg, unable to maintain for itself that temperature which is necessary for its metabolism to proceed, awaits heat from without before it can develop. Sometimes it is necessary that external conditions should pass through more than one phase before the reproductive body is fully prepared for development, as the eggs and cysts of various aquatic organisms must be dried and afterwards moistened, or frozen and afterwards thawed, if they are to develop. External conditions must keep the body as a whole in a suitable state for development to continue ; and they exert upon sundry of its parts similar influences, as each part acquires the power of reacting to them in specific ways. We have already noted the effect of light upon the development of pigment in regions which are otherwise fitted to possess it. Many other such actions of external conditions have been found to take place. Thus the direction of growth, and so the form of the colony, of hydroid zoophytes is affected by light and by gravity. If a piece cut from the stem be placed vertically it will grow new roots and tentacles, the tentacles always at the end which is placed uppermost, the roots always at the lower ends. The power of forming each of these members is exercised only in certain conditions of gravity. (ii) Besides the influences which cause development to proceed on its predetermined course, there are others which affect it so as to modify its results.[1] We have already alluded to these (p. 8), and have shown how light, salinity, reaction of the medium, temperature, various stimuli which affect the extent to which organs are used, etc., exercise such an influence both upon the young and upon adults. (iii) The functioning of the body is even more under the influence of the surroundings than is its development. In part this influence is indirect, being due to that which we have seen to be exercised, during the evolution of the race and the development of the individual, upon organization ; for this cannot be modified without corresponding effects upon function. This part is permanent. Another part is direct, and that is transitory. The permanent features of the activity of each organism, the routine of its physiology, as that limbs move and the stomach digests, must, of course,

[1] The distinction here drawn between two kinds of external influences upon development is perhaps in the last analysis an artificial one, but it is convenient.

have come into being with the organs themselves, and owes as much as, and no more than, they do to the influence of the environment. But its transitory variation, the reaction to the surroundings of the moment, betrays a further influence of the outer world. It may be due to influences exerted immediately upon the protoplasm which does the work, as when a high temperature keeps a cold-blooded animal active; or it may be due to influences exerted through sensitive surfaces, from which impulses are transmitted to the acting organs. Cases of the latter kind are the more conspicuous in the external activities of animals, and we must now briefly consider them.

Activity on the part of an animal may be started from within it, as when hunger induces it to search for food, or from without, as when the sighting of its enemy causes it to take flight; but even internally started activity is influenced from without, as that of a hunting animal may be guided by scent. How do the external influences work upon the organism? When an animal wanders in search of food, or a mate, or a spot in which to lay its eggs, how is its journey directed? When it strives with its foe or prey, how are its actions decided? In these, as in all other activities, its procedure is directed to meet its necessities. How is this direction achieved? Obviously, stimuli received from without through specific organs of perception and other sensitive regions of the surface of the body play a part in it. But what is this part? As in the problem of the origin of structural variation, so here also there are two views as to the extent to which the organism is autonomous.

(1) One of these is known as the *theory of Tropisms*. According to this theory, the body is a piece of mechanism so constructed—partly, no doubt, as a result of evolution, and partly as the result of stimuli received in the course of its individual life (which result, when it affects the nervous system, is known, upon this theory, as memory)—that it reacts in a certain fixed way to every stimulus. These definite responses to stimuli are known as "tropisms." They are seen in their simplest form in protozoa and other low organisms, which, for instance, crowd mechanically towards, or away from, light, chemical substances dissolved in the water, etc. Thus green protozoa such as *Euglena* and *Volvox*, the Green Hydra, and the larva of the Acorn Barnacle (*Balanus*), are "positively phototropic," that is, move towards the light, and various polyps and tube-dwelling worms bend towards it, while the larvæ of the Blowfly are negatively phototropic, seeking darkness. These facts are explained as due to the existence in the animals of symmetrical nervous or other mechanisms which counteract one another. It is supposed

that these opposing mechanisms only work equally when their possessor faces towards or away from the light, so that both sides are stimulated equally, and that thus they keep it straight. It is assumed that there are other mechanisms which facilitate forward and backward movement to and from the light, and work oppositely in positively and negatively phototropic animals. In order to explain the fact that an animal will at one time seek a stimulus which at other times it avoids—as a caterpillar when it is feeding will move towards the sunlight, in which plants grow, and when it is about to pupate seeks darkness—it is supposed that something occurs in the physiology of the animals which reverses the working of the mechanism. Instincts, such as those of feeding, mating, etc., are but complicated tropisms. In the highest animals (Arthropoda, Vertebrata, etc.) a further complication is brought about by the existence of what is known as "associative memory." This is defined, upon the theory of tropisms, as "that mechanism by which a stimulus produces not only the direct effects determined by its nature, but also the effects of entirely different stimuli which at some former period by chance attacked the organism at the same time with the given stimulus." Thus an image or odour may call up the memory of surroundings which were present on a former occasion when it impressed the animal, and may modify the actions of the latter accordingly. So a dog which has been beaten will shrink at the sight of a stick. (2) Another theory analyses behaviour differently. According to it the reaction of animals to stimuli is not thus rigidly predetermined. It holds that the organism tends always to discharge its energy in activity in ways which are determined partly by its constitution and partly by its temporary physiological condition and tend to be advantageous to it in that condition, and that this discharge is modified by stimuli from without which inhibit or reverse it when its results are unfavourable, or would normally be so. It is constantly attempting action and modifying it when it proves harmful. This is known as the method of *Trial and Error*. It may be illustrated by observations made by Jennings upon the behaviour of *Paramecium*. That animal is incessantly in motion, and appears to be attracted towards a moderate warmth, weak acids, etc., while it is repelled by warmth above 25° C., strong acids, alkalies, etc. It might seem that this was due to simple tropisms, in which the effect of the stimulus was to slow or quicken the working of the cilia on the side nearest to it. What really happens, however, is by no means so simple. Not all the conditions which appear to act as stimuli upon *Paramecium* actually do so, and the effect of all those which do stimulate it is to

repel it. The animal on receiving a stimulus first withdraws, by a definite backward movement due to a reversal of the working of its cilia, from the direction of the stimulus. It then turns towards the dorsal side and swings the front end of its body round in a circle

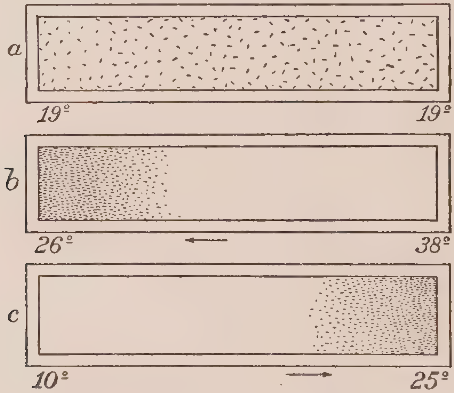

FIG. 424.—The reaction of *Paramecium* to heat and cold.—From Jennings, after Mendelssohn.

At *a*., the infusoria are placed in a trough both ends of which have a temperature of 19° C. They are equally scattered. At *b*., the temperature of one end of the trough is raised to 38° C., while the other is only 26° C. The infusoria collect at the end which has the lower temperature. At *c*., one end has a temperature of 25° C., while the other is lowered to 10° C. The animals now collect at the end which has the higher temperature.

with that side outwards till it comes to point in some direction in which the stimulus is not acting, and in that direction it swims forwards. Thus the approach to conditions which appear to attract it is in reality due to the avoidance of the relatively less agreeable

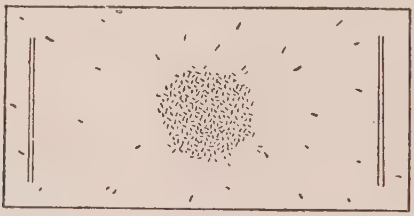

FIG. 425.—*Paramecia* collecting in a drop of $\frac{1}{50}$ per cent. acetic acid.—From Jennings.

conditions which it meets in other directions. That, for instance, the animals collect, as they may be seen to do, in clusters in regions where there is an optimum of some condition, such as temperature or acidity, is due to their entering such regions in the course of their

explorations, and being caused to remain there by the fact that when they attempt to leave they are repelled by the less favourable conditions outside. They behave, in short, as if they were trying different directions of movement and abandoning those in which it proved undesirable to proceed. It is claimed that this type of behaviour is found throughout the animal kingdom, from the *Amœba* to Man. The exhibition of it by the higher animals is illustrated by the case of a dog which, being given a stick to carry through a gap in a hedge, seized it again and again in various places and tried, but failed in its endeavour, owing to the stick striking the sides of the gap; till, happening to take hold of it by one end, the animal succeeded in passing through the hedge, after which, memory coming to its aid, it was able to repeat the task. Between these theories we shall not attempt to decide. It seems not im-

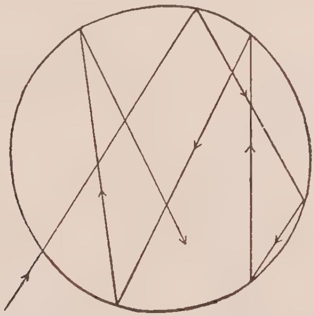

FIG. 426.—The path followed by a single *Paramecium* in a drop of acid.—From Jennings.

possible that a compromise between them may be reached. In any case, the fact must be noted that both alike allow an initiative to the organism in the starting of activity, by whatever shackles its actions be limited.

Here, then, we are back at the point from which we started. Self-advantaging activity is the mark of living beings; and though a part of that activity is the immediate result of stimuli from without, another part, both in development and in behaviour, is started from within. Inevitably there arises the question: how far is this a real initiative? Is it not, in the long run, only a feature of the process of change which goes forward in the world, since the animal is but a part of the world out of which it arose, and whose forces, in however original a manner, are at work in it? Does the animal, in fact, form with the rest of the world a closed system, into which no new force is introduced? To this question science has as yet no answer

to give. It is true that at least in one organism, that is, in Man, there appears to be such a factor, namely, his consciousness, which does intervene from outside; for it is evident that unless consciousness impressed his nervous system he could neither speak nor write, nor, perhaps, even think about it. But when we thus regard consciousness as an external factor we are assuming that the system is a material one, whereas it may comprise psychical as well as physical factors. If that were the case, then consciousness might be a part of the organism, which is part of the world, and we should still have no proof that in organisms a real initiative affects the course of the world's events. With these problems, however, the Zoologist need not be concerned. For him there is inspiration enough in the fact that animals exist—that in a world of infinite possibilities but also of infinite dangers, these most frail and transitory of natural objects preserve their kind by a struggle which seems ever more admirable the more closely it is regarded.

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(References to Figures are printed in thick type.)